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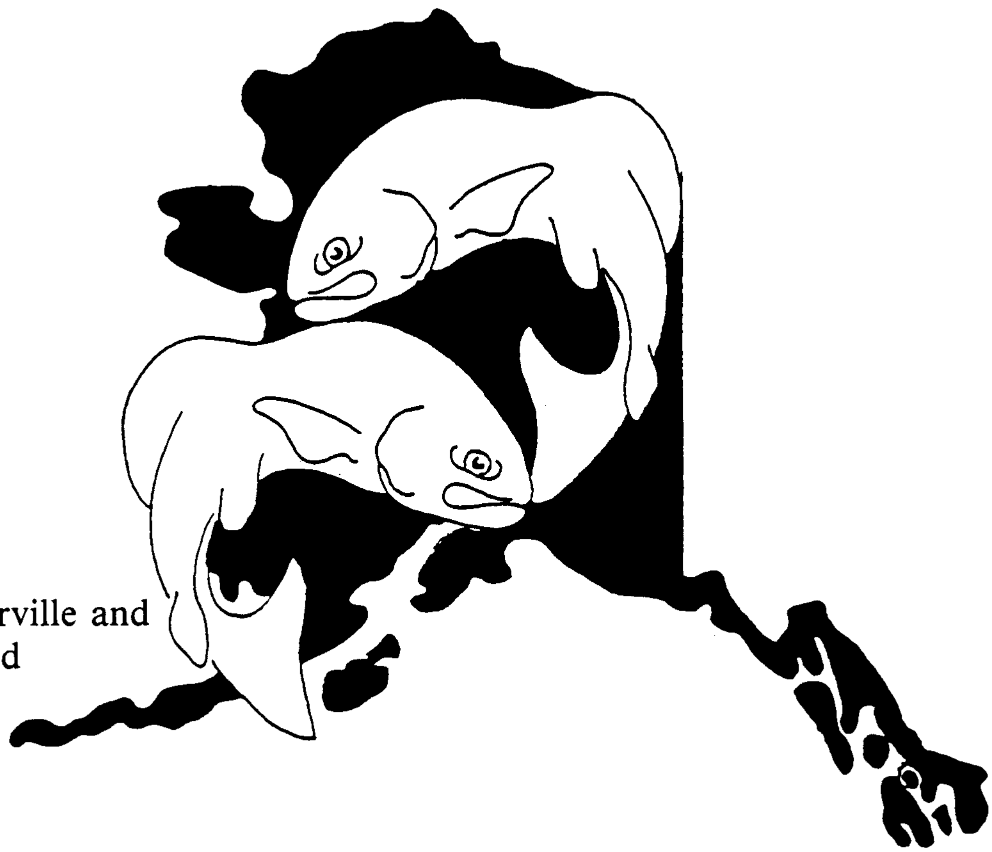

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STOCK ASSESSMENT AND BIOLOGICAL CHARACTERISTICS OF BURBOT IN LAKES OF INTERIOR ALASKA DURING 1986[1]

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ABSTRACT

Abundance and/or indices of abundance of burbot, (*Lota lota* Linnaeus), were estimated for populations in 20 Interior Alaskan lakes. Sampling occurred from June into October 1986. Although burbot 300 millimeters (total length) and longer were captured, burbot were not fully recruited to the gear (hoop traps) until they reached 450 millimeters. Abundance of large (fully recruited) burbot estimated with mark-recapture experiments was greatest in Paxson (9,111), Louise (6,990), Moose (2,027), and Tolsona (1,901) Lakes.

Mean catch per unit of effort of large burbot was above 1.00 burbot per 48-hour set for populations in Tyone, Paxson, and Tolsona Lakes. In June large burbot tended to be in the shallows and small burbot in deeper water; by summer, both large and small burbot were at all depths; and by fall both large and small burbot were in shallow water. Mean catch per unit of effort for large burbot was high in June and July, dropped in August and September, and rose in October in most lakes.

Size composition of burbot populations varied widely among lakes with some having no large burbot at all. Recognizing the sex of mature burbot through inpection of gonads proved difficult. No differences in the growth and age of male and female burbot were found. Sex compositions of well-sampled populations were about 50/50 for burbot of all ages. Parameters in the length-weight relationships for Paxson and Harding Lakes were estimated. Small and big hoop traps caught burbot of the same size in Paxson Lake, although small hoop traps had higher catch rates.

KEY WORDS: Burbot, *Lota lota*, lakes, abundance, hoop traps, systematic design, random design, stratified design, otolith, selectivity, sex composition, mean length, length-weight, age, catch per unit of effort.

INTRODUCTION

Since 1977, 84% of the estimated harvest of burbot (*Lota lota* Linnaeus) in Alaska has come from lakes in the Tanana River drainage and in the vicinity of Glennallen (Mills 1986). Set lines and jigs fished through the ice are the most popular gear in these fisheries. Harvest of burbot in these sport fisheries has increased annually an average 30% with the greatest harvests occurring in recent years. These statistics, along with stock assessment of the burbot population in Fielding Lake since 1981 (Peckham 1985), prompted a closure of Fielding Lake to the taking of burbot from 17 May through 31 December 1984.

The purpose of this project is the stock assessment of burbot populations in lakes in Interior Alaska and the gathering of biological information germane to the productivity of these populations. Information from this project will be used to estimate the range over which sustained harvests from these stocks can be maintained. The objectives for work in 1986 are:

1) Estimation of mean Catch Per Unit of Effort (CPUE) of burbot in 20 lakes as an index of abundance;

2) Estimation of abundance of burbot in 14 lakes;

3) Estimation of mean total length (TL) of captured burbot in 20 lakes;

4) Estimation of mean length at age for burbot in 20 lakes;

5) Estimation of the parameters in the length-weight relationships of burbot populations in 20 lakes; and

6) Testing the hypothesis of equal catchability of burbot in two different sizes of hoop traps.

The study lakes in the Tanana River drainage were Fielding, Harding, Tee, West Twin, Deadman, Glacier, Sevenmile, Round Tangle, Shallow Tangle, Upper Tangle, and Landlock Tangle Lakes (Figure 1). The study lakes near Glennallen were Susitna, Tyone, Forgotten, Burnt, Moose, Tolsona, Summit, and Paxson Lakes and Lake Louise (Figure 1). Each lake chosen for this study has (or had) a popular sport fishery for burbot (according to statistics reported in Mills 1986) or is reasonably accessible to anglers. More detailed descriptions of each study lake are in the Appendix.

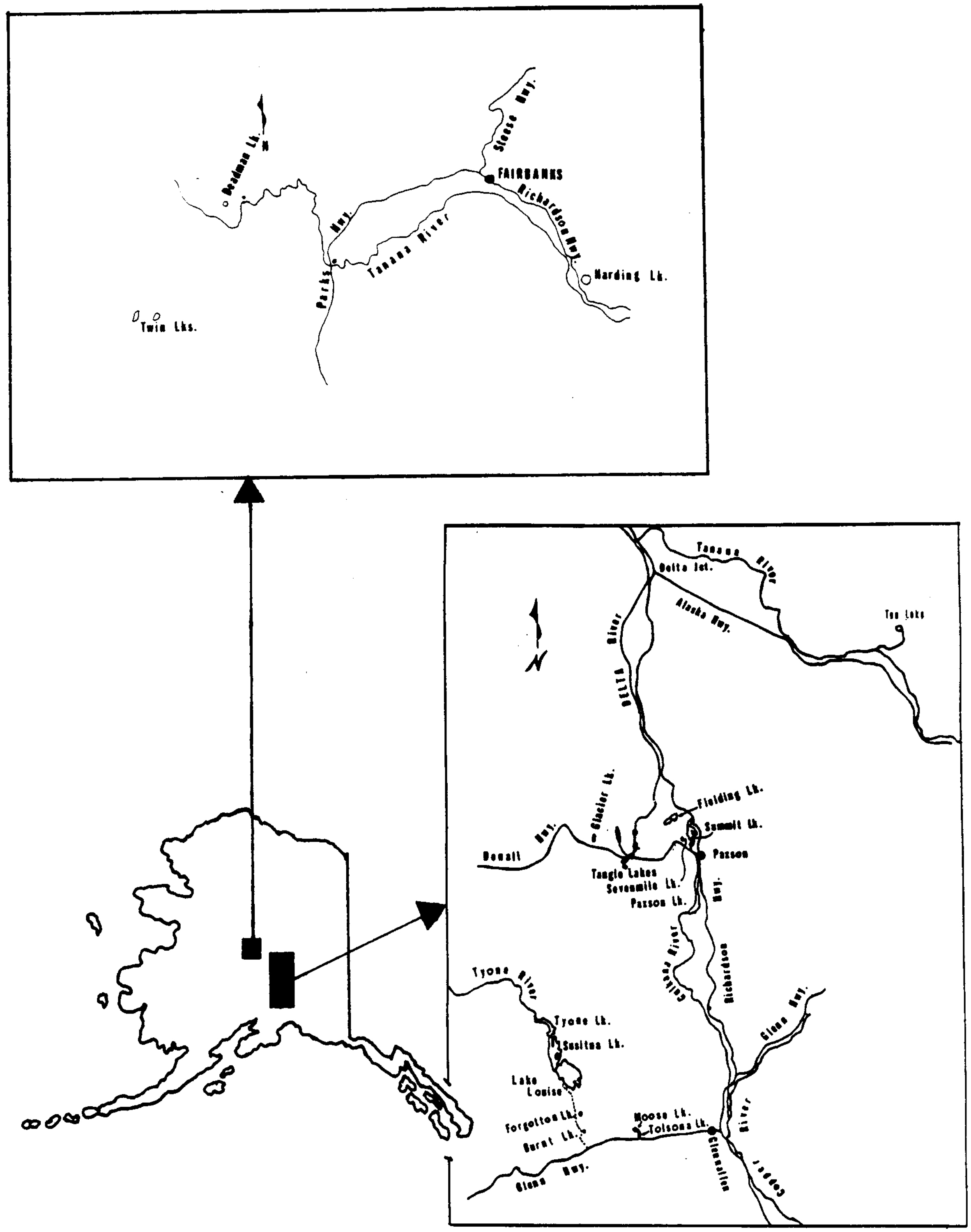

Figure 1. Location of the lakes in the Tanana River drainage and near Glennallen that were included in studies of burbot populations in Interior Alaska in 1986.

METHODS

Gear Description

Burbot were captured in two different sizes of hoop traps. The type of trap most often used in 1986 is 3.05 m long with seven 6.35 mm steel hoops (Figure 2). Hoop diameters taper from 0.61 m at the entrance to 0.46 m at the cod end. Each trap has a double throat (tied to the first and third hoop) which narrows to 0.31 m (flattened). All netting is knotted nylon woven into 25 mm bar mesh, held together with No. 15 cotton twine, and treated with an asphaltic compound. Each trap was kept stretched with two sections of 12 mm galvanized steel conduit attached by snap clips to the end hoops. A numbered buoy was attached to the cod end of the trap with polypropylene rope. Each trap was baited with Pacific herring, (*Clupea harengus pallasi* Valenciennes), cut into chunks and placed in a 500 ml perforated plastic, screw-top container. Bait containers were placed unattached in the cod end.

The other type of hoop trap used in 1986 was designed as above, only larger. These traps are 3.66 m long with all hoops 0.91 m in diameter. Hoops are fiberglass, and the spreader bars are PVC pipe. These traps were used in 1985 and were used only during one sampling event on one lake (Paxson) in 1986.

Study Design

For each sampling event but one, hoop traps were set randomly across small lakes or according to a systematic grid across large ones (Table 1). For small lakes, locations for sets were randomly selected from a grid overlay representing 125 m squares[1] placed over a map of the lake. Initially, random placement of sets for all lakes was attempted, but proved too time consuming to implement on larger lakes because of the difficulty in navigation to a set location. Therefore, the locations of sets on large lakes were chosen systematically to ease finding these locations on the lakes. First, an overlay with parallel lines was placed across a map of the lake at a randomly chosen position but with the lines in the overlay perpendicular to the long axis of the lake. Distances between adjacent lines in the overlay represented 125 m. Also, each parallel line had tick marks that represented a distance of 125 m. Next, the desired number of

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[1] The distance between traps of 125 m was chosen to eliminate gear competition. The effective fishing area of a baited trap was estimated at 0.45 ha by dividing the average CPUE in burbot caught per 48-hour set in 1985 in Fielding Lake by the density of burbot per ha from the mark-recapture experiment (Pearse and Conrad 1986). This estimated fishing area was arbitrarily increased to 1.25 ha to ensure elimination of gear competition; this area corresponds to traps set at a distance of 125 m. Similar calculations from data collected this year support this distance as being sufficient to eliminate gear competition.

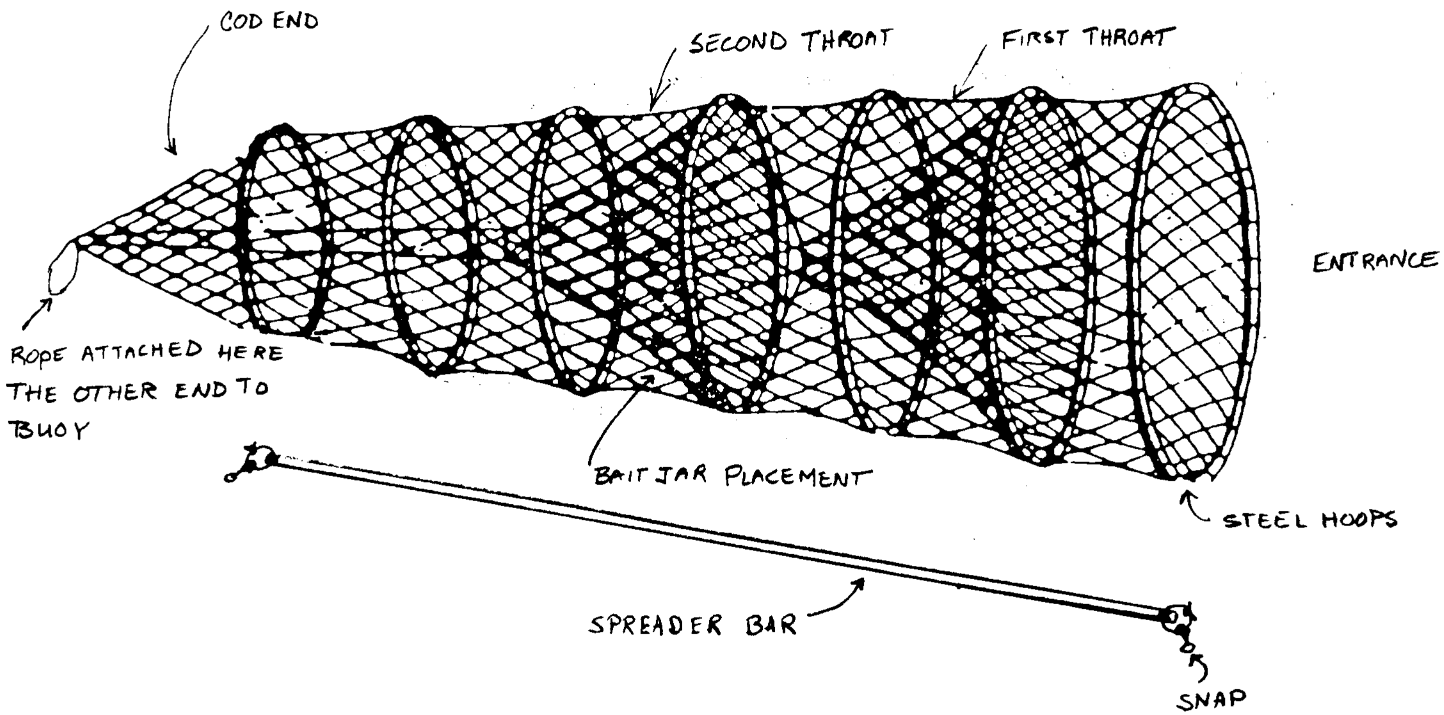

Figure 2. Schematic drawing of hoop traps most commonly used to catch burbot in Interior Alaska in 1986.

Table 1. Numbers of sets, dates of sampling events, and sampling designs for the stock assessment of burbot populations in 20 lakes in Interior Alaska in 1986.

Lake	Area (ha)	Sampling: Event	Dates	Design	Number of Sets
Fielding	538	1	7/28-01	systematic[1]	236
		2	8/21-25	systematic	150
Round Tangle	155	1	7/21-25	random	99
		2	8/16-18	random	61
Shallow Tangle	130	1	7/21-25	random	96
		2	8/16-18	random	40
Upper Tangle	142	1	7/21-25	random	98
		2	8/18-20	random	100
Landlock Tangle	219	1	7/20-24	random	80
Sevenmile	34	1	7/24-8/09	random	56
		2	9/17-21	random	20
Harding	1,000	1	9/08-14	systematic	228
Tee	162	1	6/11-19	random	120
West Twin	680	1	7/29-02	systematic	78
Glacier	172	1	7/16-20	random	80
Deadman	207	1	8/04-08	random	40

-Continued-

Table 1. Numbers of sets, dates of sampling events, and sampling designs for the stock assessment of burbot populations in 20 lakes in Interior Alaska in 1986 (continued).

Lake	Area (ha)	Sampling: Event	Dates	Design	Number of Sets
Tolsona	130	1	9/23-27	systematic	150
		2	10/08-10	systematic	75
Paxson	1,575	1	7/07-12	systematic	245
		2	8/04-14	systematic	300
		3	9/16-20	systematic	120
Summit	1,651	1	7/12-17	systematic	379
		2	8/26-04	systematic	400
Louise	6,519	1	6/25-28	systematic	248
		2	8/19-02	systematic	499
Susitna	3,816	1	6/27-29	random	100
		2	8/13-19	systematic	189
Tyone	389	1	6/26-28	random	49
		2	8/11-13	random	76
Moose	130	1	6/02-14	random	225
		2	8/04-08	random	100
Burnt	24	1	6/04-08	random	60
		2	6/16-20	random	60
Forgotten	7	1	6/03-07	random	30
		2	6/16-20	random	20
TOTALS	17,680		6/04-10/10		4,907

[1] Systematic and random designs are described in the text.

sets was compared with the tick marks that were over the water on the map; parallel lines were randomly excluded until the tick marks and the desired number of sets were similar. Traps were set in transects corresponding to the position of each remaining parallel line. However, the location of the first set along each transect was randomly chosen with every subsequent set along that transect at 125 m. The desired number of sets for each lake and each survey design was chosen according to the rules in Pearse and Conrad (1986) for the first sampling event. The number of sets for the second sampling event was chosen according to rules in Robson and Regier (1964) for sample size in mark-recapture experiments and with estimates of CPUE from the first sampling event.

The one exception to the random and systematic designs is the third sampling event in Paxson Lake. Transects were located starting at the southern end of the lake as described above. However, all transects were fished moving north up the lake until 120 sets had been made. Both the large and the small hoop traps were fished with the type of the first trap fished randomly chosen. Thereafter, big and small traps were fished alternately along the transects. Results from this third design were used to detect differences in the numbers and lengths of burbot caught in each type of trap.

Traps were set and retrieved beginning on one end of the lake in progression to the other end. In the larger lakes, two crews (three members per crew: one person piloted the boat and recorded data while the other two handled traps and took biological information from the burbot caught) set and retrieved traps simultaneously. In smaller lakes, crews worked alone. Each crew set and retrieved 50 to 80 traps per eight-hour day. The time of setting and retrieving each set was recorded to the minute. The depth of each set was measured with a fathometer. Each hoop trap was soaked for approximately 48 hours (a set) to optimize catch (Pearse and Conrad 1986). Each new set started with fresh bait, and old bait was discarded on shore.

Burbot were placed in a plastic tank during sampling. To mitigate the effects of handling stress on burbot captured in deep water, water was pumped into the tank from a hose with an inlet below the thermocline. Each burbot was measured and those longer than 300 mm TL were finclipped (pelvic fin) and tagged with an anchor-type, individually numbered Floy tag inserted at the base of the dorsal fin. Burbot that exhibited stress associated from deep-water removal (usually an expanded gas bladder) or trap-inflicted injury were weighed and disected. Otoliths were removed from these burbot and their sex and maturity were recorded.[2] Ages of burbot were estimated from whole, polished otoliths by counting annuli.

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2 During the second sampling event, burbot were separated into 50 mm length groups and five burbot were randomly selected from each group for disec tion from populations in Tolsona, Paxson, Tyone, Summit, Susitna, and Forgotten Lakes and Lake Louise.

Estimation of Abundance

In those lakes with two sampling events, abundance of burbot was estimated with a mark-recapture experiment with the Chapman modification of methods developed by Petersen (see Ricker 1975). A one-week to two-month hiatus occurred between sampling events in the same lake to permit tagged fish to mingle with untagged fish. The longer waits occurred on the larger lakes. Recovery rates of tagged fish by size were used to detect size selectivity of the sampling gear. Also, methods of Robson and Flick (1965) were used to detect growth recruitment to several burbot populations between sampling events.

Calculation of Mean CPUE

Means from the random designs were calculated according to procedures described in Sukhatme et al. (1984):

1) $$\overline{CPUE} = \bar{x} = \sum_{j=1}^{m} x_j \quad \text{where} \quad x_j = \frac{C_j}{E_j}$$

2) $$V[\overline{CPUE}] = \sum_{j=1}^{m} \frac{(\bar{x}_j - x)^2}{m\ (m - 1)}$$

where:

- C = catch;
- E = effort in units of 48 hours; and
- m = number of sets.

Means from the systematic designs were calculated for each burbot population according to procedures described in Sukhatme et al. (1984) for multistage sampling and from Wolter (1984) for unbiased estimation of variance from systematically drawn samples:

3) $$\overline{CPUE} = \bar{\bar{x}} = \sum_{i=1}^{n} \sum_{j=1}^{m_i} x_{ij} \quad \text{where} \quad x_{ij} = \frac{C_{ij}}{E_{ij}}$$

4) $$V[\overline{CPUE}] = \sum_{i=1}^{n} \frac{(\bar{x}_1 - \bar{\bar{x}})^2}{n\ (n - 1)} + \sum_{i=1}^{n} \sum_{j=2}^{m_i} \frac{(x_{ij} - x_{i,j-1})^2}{2\ n^2\ m_i\ (m_i - 1)}$$

where:

- n = number of transects; and
- m = number of sets on a specific transect.

The x_{ij} were arranged in serial order for these calculations. Because the exact "area" that the average trap fished is unknown, the maximum possible number of sets is also unknown; therefore, finite population correction factors were excluded from Equations 2 and 4.

Estimates of mean CPUE were post stratified by depth according to procedures described in Sukhatme et al. (1984) and Pearse and Conrad (1986):

$$5)\qquad \overline{CPUE}_{st} = \sum_{h=1}^{L} W_h \, \overline{CPUE}_h$$

$$6)\qquad V[\overline{CPUE}_{st}] = \sum_{h=1}^{L} W_h \, V[\overline{CPUE}_h] + \sum_{h=1}^{L} \frac{(1-W_h)V[\overline{CPUE}_h]}{n}$$

where:

- L = the number of strata;
- n = the number of sets (random design) or transects (systematic design); and
- W_h = ratio of the area covered by stratum h to the area of the lake.

Average catch by depth was plotted for each sampling event in which 20 or more burbot were captured. Depths at which average catch by depth changed dramatically in these plots were chosen as the boundaries between strata. For populations sampled with the systematic design, the weights (W_h) were calculated with planimeters and bathymetric maps or were obtained from Van Whye and Peck (1968). The weights for populations that were sampled with a random design were calculated as the fractions of all sets from all sampling events within a depth stratum.

When a boundary between strata cut across a transect in the systematic design, each part of the disected transect was considered a new transect, each within its separate stratum. In those cases where such a new transect consisted of only one set, that datum was excluded from the analysis.

Stratified estimates of mean CPUE were calculated in all instances where average catch by depth changed dramatically. In these instances, unstratified estimates were calculated as well. If the two estimates (stratified and unstratified) were dissimilar by an amount greater than the arbitrary standard of half the standard error of the larger estimate, the stratified estimate was reported as the more accurate estimate. Otherwise, the unstratified estimate was given.

Age and Length

Parameters of allometric length-weight relationships for burbot were estimated with a computer program that iteratively "fits" nonlinear models to bivariate data. The algorithm of the program follows the Marquardt compromise (Marquardt 1963). Forty-four separate sets of estimates of the parameters were calculated with each calculation beginning with a new set of initial values. The initial values of the allometric constant ranged from 2.0 to 4.0 by increments of 0.2; the initial values of the linear constant ranged from 4.0 to 12.0 by increments of 2.0. The output from all forty-four operations was an isopleth diagram of the sums of squares of the residuals arising from each operation and the set of estimates which corresponded to the lowest sums of squares.

RESULTS

Abundance

Contingency table analysis of rates of recapture of tagged burbot indicates that larger burbot (≥450 mm TL) were captured at a higher rate than were smaller burbot in hoop traps (Table 2). In the six populations with enough tagged and recaptured fish to meet the assumptions of the test, significantly high χ^2 statistics occurred when 450 mm TL was one of the boundaries between two cells in the test. Further testing of data from Moose, Tolsona, and Fielding Lakes showed that significant differences in the recovery rates of tagged fish occur <u>only</u> when 450 mm TL was a boundary between groups. The rate of capture of small burbot was 23% of that for large burbot in Tolsona Lake, 31% in Moose Lake, and 44% in Fielding Lake.

No growth recruitment between sampling events in Tolsona, Fielding, and Summit Lakes was found. The hiatus between sampling events for these lakes was 11, 20, and 40 days, respectively. The test for recruitment was conducted only for small burbot in these lakes, since these fish grow faster than do larger burbot.

Because hoop traps proved selective for larger burbot, abundance of large (≥450 mm TL) and of small (<450 mm TL) burbot was estimated separately (Table 3). Of the 14 lakes in which two sampling events occurred, burbot were recaptured in 11. Paxson Lake had the greatest estimated abundance of large burbot (9,111) and Moose Lake the greatest estimated abundance of small burbot (4,343). In the seven larger lakes (>100 ha), the density of large burbot ranged from 0.4 burbot per ha in Fielding, Summit, and Round Tangle Lakes to 15.6 in Moose Lake; the density of small burbot ranged from 0.7 burbot per ha in Paxson Lake to 33.4 in Moose Lake (Figure 3). Because these study populations are closed, their abundance estimates are relevant to the first sampling event in each lake. In those lakes that are connected (Louise, Susitna, and Tyone Lakes and Upper, Round, and Shallow Tangle Lakes), no tagged fish were recovered outside of the lake

Table 2. Results of contingency table analysis of the recapture rates of tagged burbot by length.

Lakes[2]	Test Breaks[1] (mm TL) < 400 450 500 550 600 >	Significant Tests[3]
Tolsona and Moose	----------><----><---------------	P<.005
	----------><---------------------	P<.005
	<----><---------------	
Fielding	----><----><--------------------	.025<P<.05
	----------><---------------------	.025<P<.05
	----><---->	
Paxson	----------------------------><---	
Summit and Forgotten	----><--------------------------	

[1] Each group of lines corresponds to a battery of tests (there are four groups). The symbols "><" correspond to boundaries between adjacent categories in a test.

[2] The same battery of tests with the same results for different populations are reported simultaneously in a single group.

[3] Tests are RxC contingency tables and χ^2 statistics for $H_o: p_i = p$ where p_i = probability of catching a burbot in the ith length group. The numbers of marked fish caught and not caught were used in the contingency table. The first test in a battery had length groups of 50 mm TL except where data were grouped into larger categories to meet the requirements of the test. If the null hypothesis was rejected, further tests in a battery were done (if possible) to estimate at what length the probability of capture changed.

Table 3. Estimated abundance (N) of small (<450 mm TL) and large burbot (≥450 mm TL) from 11 lakes in Interior Alaska in 1986.[1]

Lake	Size	Number of Marked Burbot Released	Number Caught Second Event	Number Recaptured	$\hat{N}$	$SE[\hat{N}]$[2]	$CV[\hat{N}]$[3]
Paxson	large	461	354	17	9,111	1,996	21.9%
	small	51	82	3	1,078	452	41.9%
Louise	large	219	285	8	6,990	2,131	30.5%
	small	82	20	0			
Moose	large	808	177	70	2,027	177	8.7%
	small	723	113	18	4,343	875	20.1%
Tolsona	large	517	491	133	1,901	120	6.3%
	small	163	128	10	1,922	513	26.7%
Summit	large	49	62	4	629	234	37.2%
	small	153	176	11	2,271	584	25.7%
Fielding	large	59	49	13	213	41	19.2%
	small	184	129	18	1,265	248	19.6%
Round Tangle	large	20	11	4	49	14	27.5%
	small	115	61	3	1,797	764	42.5%
Forgotten	large	3	3	2	4	1	13.9%
	small	62	59	33	110	8	7.6%
Burnt	large	4	1	1	4	0	0.0%
	small	20	15	10	30	3	11.3%
Shallow Tangle	large	2	1	1	2	0	0.0%
	small	73	31	0			
Sevenmile	large	0	0	0			
	small	79	73	10	537	133	24.8%

[1] Abundance of burbot in Landlock Tangle, Upper Tangle, Susitna, and Tyone Lakes could not be estimated because no burbot were recaptured in these lakes.
[2] Standard error.
[3] Coefficient of variation.

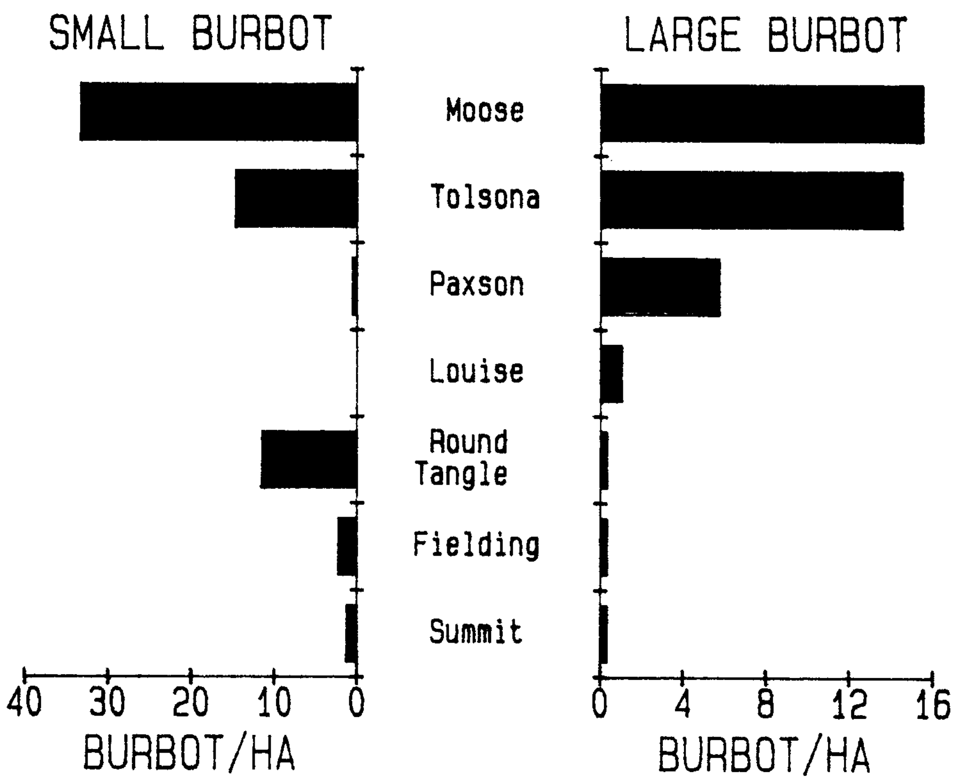

Figure 3. Estimated density of large (≥450 mm TL) and small (<450 mm TL) burbot in seven large (>100 ha) lakes in Interior Alaska in 1986.

in which they had been released. Only a few recaptured burbot had lost their tags. More detailed statistics on catches of marked and unmarked burbot are in Appendix Table 1.

Mean CPUE

Mean CPUE ranged from 7.15 large burbot per set in Tolsona Lake for the sampling event in early October (Table 4) to 0.03 large burbot in Shallow Tangle Lake in July and August (Table 5). Because abundance estimates were split into large and small burbot, so too were estimates of mean CPUE. No or few large burbot were caught in Burnt, Forgotten, Glacier, or Sevenmile Lakes. Only one burbot was caught in Deadman Lake. Post stratification by depth markedly improved estimates of mean CPUE for small burbot caught during the June sampling events in Lake Louise and Susitna Lake and for for all burbot caught during the single event in late July-early August in West Twin Lake. Post stratification was tried in 11 other instances with little or no improvement over results from unstratified designs. Frequency of sets by depth and of average catch by depth of large and small burbot are in Appendix Figures 1-9 for most lakes.

Post stratification proved inconsistently fruitful because burbot in most lakes were concentrated in June and July, dispersed in July through August, and concentrated again in September. For instance, average catches of large burbot were higher in the shallows of Susitna Lake in late June while average catches of small burbot during the same sampling event were greater in the depths of the lake (Figure 4); yet by mid-August large and small burbot had dispersed and mixed through all depths. Both large and small burbot were mixed and dispersed through all depths in Summit Lake during the first sampling event in July (Figure 5); but both groups were concentrated in the shallows of this lake during the second sampling event in late August-early September. Similar behavior can be seen in the population in Lake Louise (see Appendix Figures 7). Other lakes were either sampled only in July and August and have populations dispersed through all depths, or are too shallow for comparisons of average catch by depth.

Mean CPUE also changed seasonally among sampling events by declining in summer and rising in the fall, especially for large burbot (Table 6). Mean CPUE of large burbot changed significantly between sampling events for four of the nine populations that were sampled for the first time in June or July and sampled for the second time in August. In these four lakes (Paxson, Louise, Susitna, and Tyone), the mean CPUE of large burbot dropped on average 46%. Mean CPUE of burbot in all nine populations changed significantly for populations in Tyone (up 147%) and Upper Tangle (down 10%) Lakes and Lake Louise (down 69%). For the two populations that were sampled for the first time in August or September, mean CPUE changed significantly for large burbot in Tolsona Lake and small burbot in Sevenmile Lake (up 125% and 80%, respectively).

Table 4. Estimated mean CPUE from transect and stratified transect sampling events in Fielding, Harding, Louise, Paxson, Summit, Susitna (second event), Tolsona, and West Twin Lakes in 1986.

Lakes and Dates	Strata	Number of Sets and	Transects	Small[1] Burbot CPUE	SE	Large Burbot CPUE	SE
FIELDING							
7/28-8/01	All Depths	236	35	0.87	0.13	0.26	0.06
8/21-25	All Depths	150	17	0.90	0.18	0.36	0.09
HARDING							
9/08-14	All depths	228	18	0.27	0.05[2]	0.29	0.06
LOUISE							
6/25-28	0-10m (15%)[3]	117	27	0.09	0.04		
	10m + (85%)	110	27	0.58	0.13		
	All Depths	227/246	54/19[4]	0.51	0.09	0.97	0.13
8/19-9/02	All Depths	486	38	0.16	0.04	0.60	0.06
PAXSON							
7/07-12	All Depths	240	36	0.34	0.06	2.28	0.17
8/04-14	All Depths	296	56	0.26	0.05	1.24	0.10
SUMMIT							
7/12-17	All Depths	372	68	0.51	0.06	0.15	0.03
8/26-9/04	All Depths	395	67	0.46	0.08	0.16	0.03
SUSITNA							
8/13-19	All depths	187	38	0.54	0.13	0.25	0.06
TOLSONA							
9/23-27	All Depths	150	11	1.12	0.68	3.98	1.24
10/08-10	All Depths	75	12	1.63	0.32	7.15	0.68
WEST TWIN							
7/29-8/02	0-15m (38%)	26	9	0.00	0.00		
	15m + (62%)	52	6	2.90	0.55		
	0-10m (25%)	49	12			0.90	0.39
	10m + (75%)	27	6			4.96	0.99
	All Depths	78	15	1.80	0.46	3.95	0.53

-Continued-

Table 4. Estimated mean CPUE from transect and stratified transect sampling events in Fielding, Harding, Louise, Paxson, Summit, Susitna (second event), Tolsona, and West Twin Lakes in 1986 (continued).

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[1] Small burbot are shorter than 450 mm TL while large burbot are that long or longer.

[2] Those instances when stratified estimates were tried but not used (see text) are designated with unstratified estimates written in italics.

[3] The percentages are the values of the weights (W_h) used in the stratified estimates.

[4] When two entries are joined by "/", the first entry is the number of sets (or transects) used to estimate the mean CPUE for small burbot while the second entry is the number of sets (or transects) used to estimate the mean CPUE for large burbot.

Table 5. Estimated mean CPUE from random and stratified random sampling events in Burnt, Forgotten, Glacier, Landlock Tangle, Moose, Round Tangle, Sevenmile, Shallow Tangle, Susitna (first event), Tee, and Tyone, and Upper Tangle Lakes in 1986.

Lakes and Dates	Strata	Number of Sets	Small[1] Burbot CPUE	Small[1] Burbot SE	Large Burbot CPUE	Large Burbot SE
BURNT						
6/04-08	All depths	60	0.57	0.11	Few Caught	
6/16-20	All depths	60	0.25	0.06	Few Caught	
FORGOTTEN						
6/03-07	All depths	6[2]	1.71	0.85	Few Caught	
6/16-20	All depths	20	1.47	0.36	Few Caught	
GLACIER						
7/16-20	All Depths	80	0.27	0.08	None Caught	
LANDLOCK TANGLE						
7/20-24	All Depths	80	0.51	0.08	0.18	0.05
MOOSE						
6/02-14	All depths	225[3]				
8/04-08	All depths	100	1.32	0.14	2.03	0.15
ROUND TANGLE						
7/21-25	All Depths	97	1.41	0.15	*0.22*	*0.05*[4]
8/16-18	All Depths	60	1.12	0.15	0.19	0.06
SEVENMILE						
8/05-09	All Depths	55	2.13	0.35	None Caught	
9/17-21	All Depths	20	4.82	0.67	None Caught	
SHALLOW TANGLE						
7/21-25	All Depths	96	0.88	0.12	0.03	0.02
8/16-18	All Depths	40	0.95	0.21	0.03	0.03
SUSITNA						
6/27-29	0-15m (84%)[5]	79	0.26	0.07		
	15m + (16%)	20	1.27	0.22		
	All Depths	99	0.42	0.07	*0.40*	*0.07*

-Continued-

Table 5. Estimated mean CPUE from random and stratified random sampling events in Burnt, Forgotten, Glacier, Landlock Tangle, Moose, Round Tangle, Sevenmile, Shallow Tangle, Susitna (first event), Tee, and Tyone, and Upper Tangle Lakes in 1986 (continued).

Lakes and Dates	Strata	Number of Sets	Small Burbot		Large Burbot	
			CPUE	SE	CPUE	SE
TEE						
6/11-19	All Depths	120	0.03	0.02	0.04	0.02
TYONE						
6/26-28	All depths	49	0.43	0.12	*2.53*	*0.35*
8/11-13	All depths	76	*1.06*	*0.16*	1.04	0.15
UPPER TANGLE						
7/21-25	All Depths	96	*0.97*	*0.01*	0.49	0.10
8/18-20	All Depths	100	*0.87*	*0.01*	0.40	0.08

[1] Small burbot are shorter than 450 mm TL while large burbot are that long or longer.

[2] There was no information on time of set for five sets during the first event. Also, four sets soaked for only one day during the first event. Seventy-nine fish were caught in these nine sets; eight fish were caught in the remaining six sets.

[3] Catches could not be separated into catches of small and of large burbot by set for this event.

[4] Those instances when stratified estimates were tried but not used (see text) are designated with unstratified estimates written in italics.

[5] The percentages are the values of the weights (W_h) used in the stratified estimates.

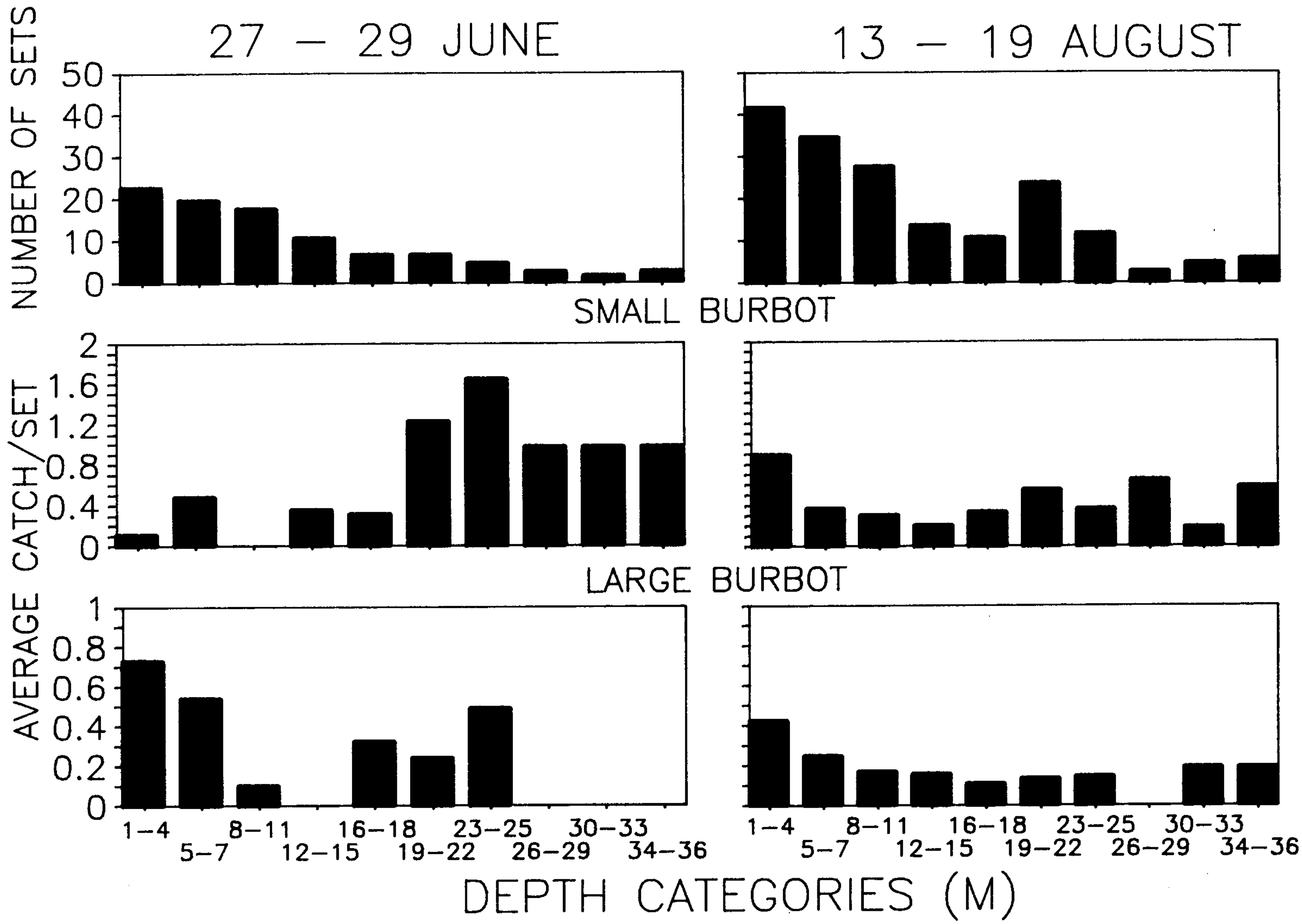

Figure 4. Frequency of sets and average catch by depth of small (<450 mm TL) and large (≥450 mm TL) burbot for the sampling events in Susitna Lake in 1986.

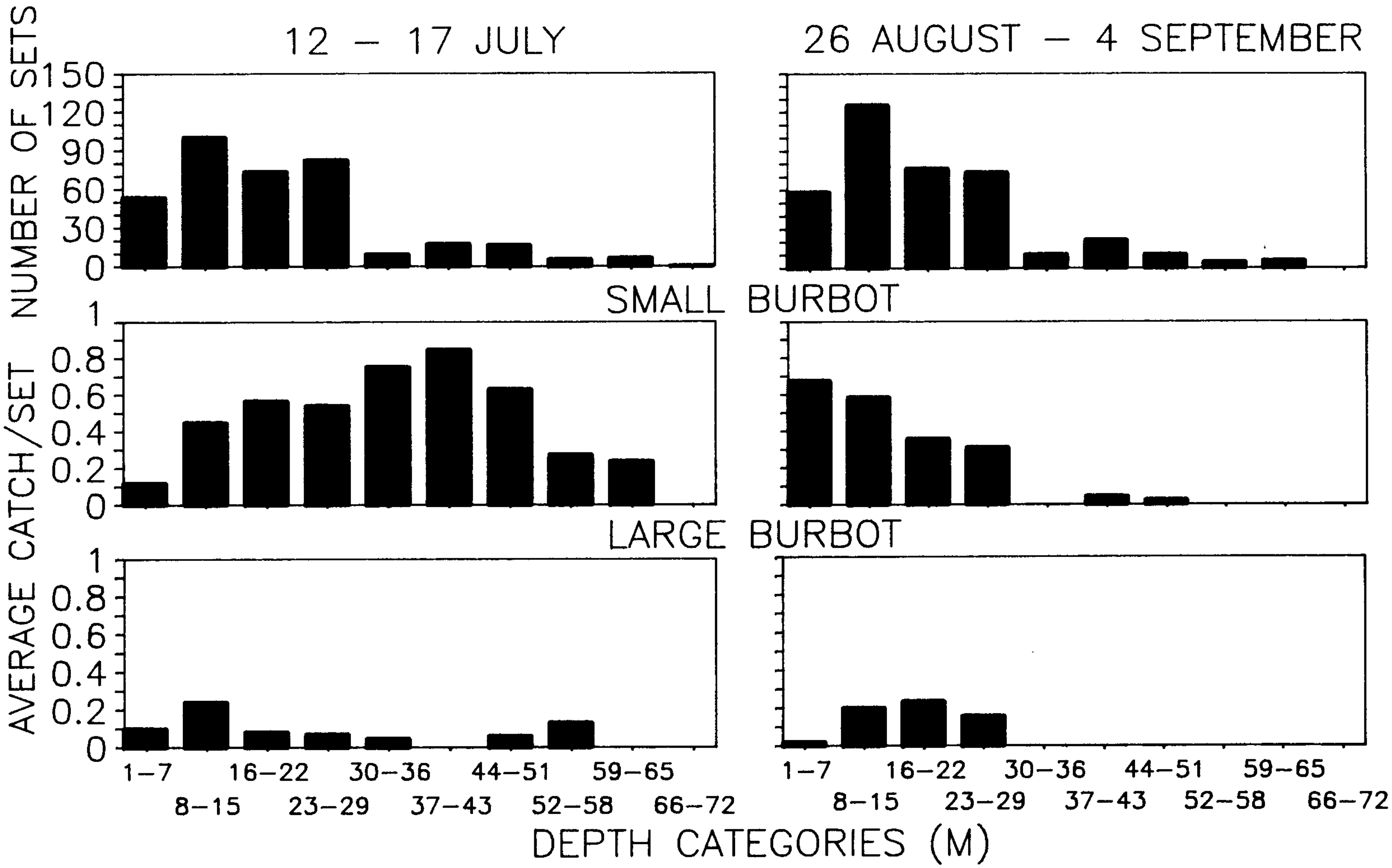

Figure 5. Frequency of sets and average catch by depth of small (<450 mm TL) and large (≥450 mm TL) burbot for the sampling events in Summit Lake in 1986.

Table 6. Change in mean CPUE of small (<450 mm TL) and large (≥450 mm TL) burbot between sampling events in Burnt, Fielding, Forgotten, Louise, Paxson, Round Tangle, Sevenmile, Shallow Tangle, Summit, Susitna, Tolsona, Tyone, and Upper Tangle Lakes in 1986.

		Small Burbot			Large Burbot		
Lakes	Dates	CPUE	%Δ	t[1]	CPUE	%Δ	t
JUNE/JUNE							
Burnt	6/04-08	0.57					
	6/16-20	0.25	-56%	-2.55*[2]			
Forgotten	6/03-07	1.71					
	6/16-20	1.47	-14%	-0.26			
JUNE/AUGUST							
Louise	6/25-28	0.51			0.97		
	8/19-9/02	0.16	-69%	-3.55**	0.60	-38%	-2.58**
Susitna	6/27-29	0.42			0.42		
	8/13-19	0.54	29%	0.81	0.25	-40%	-1.84*
Tyone	6/26-28	0.43			2.53		
	8/11-13	1.06	147%	3.15**	1.04	-59%	-3.91**
AUGUST/SEPTEMBER							
Sevenmile	8/05-09	2.13					
	9/17-21	4.80	125%	3.53**			
SEPTEMBER/OCTOBER							
Tolsona	9/23-27	1.12			3.98		
	10/08-10	1.63	46%	0.68	7.15	80%	2.24**
JULY/AUGUST							
Fielding	7/28-8/01	0.87			0.26		
	8/21-25	0.90	3%	0.14	0.36	38%	0.92
Paxson	7/07-12	0.34			2.28		
	8/04-14	0.26	-24%	-1.02	1.24	-46%	-5.27**
Round	7/21-25	1.41			0.22		
Tangle	8/16-18	1.12	-21%	-1.37	0.19	-14%	-0.38
Summit	7/12-17	0.51			0.15		
	8/26-9/04	0.46	-10%	-0.50	0.16	7%	0.24
Shallow	7/21-25	0.88			0.03		
Tangle	8/16-18	0.95	8%	0.29	0.03	0%	0.00
Upper	7/21-25	0.97			0.49		
Tangle	8/18-20	0.87	-10%	-7.07**	0.40	-18%	-0.70

[1] Student's t.
[2] * (0.05<P<0.10) ** (P<0.05)

Mean CPUE has a somewhat asymptotic relationship when plotted against density in burbot per ha for both large and small burbot (Figure 6). Only the estimates of mean CPUE for the first sampling events were used in this comparison because the abundance estimates corresponded to these events.

Age and Length

Mean length of large and small burbot varied among lakes and among sampling events in lakes (Table 7). Tee Lake contained on average the largest burbot fully recruited to the gear (624 mm TL) with populations in Paxson Lake and Lake Louise the next largest (562 to 599 mm TL over two sampling events in each lake). Round Tangle Lake contained the smallest of the fully recruited burbot (470 to 479 mm TL across two sampling events). All the estimates of mean lengths were similar between sampling events in the same lake except for populations in Lake Louise and Susitna Lake. Estimated mean lengths of both small and large burbot in Lake Louise "dropped" 20 and 30 mm, respectively, between sampling events on 25-28 June and on 19 August - 2 September. For populations of small and large burbot in Susitna Lake, the "drop" in the estimated mean lengths was 21 and 31 mm, respectively, between sampling events on 27-29 June and on 13-19 August. Length-frequency histograms of sampled burbot are in Appendix Figures 10-12.

Information on age and sex composition and mean length at age were reported for populations for which data from at least 20 fish were available (Table 8). Of the nine populations that met this criterion, data were extensive enough on four populations (from West Twin, Paxson, and Fielding Lakes, and Lake Louise) to indicate trends in length at age for both sexes (Figure 7). No differences in growth between sexes were apparent in any of these four populations. Standard errors for estimates of length at age are in Appendix Table 2. Estimates of sex composition of burbot varied considerably from 50/50 for those populations for which there are little data (Table 9). For those populations for which there are more data, the sex ratio is near, or at, 50/50. Males and females were at near equal abundance at all ages in Fielding, Paxson, and West Twin Lakes (Figure 8); females outnumbered males after age 7 in Lake Louise.

Recognition of the sex of burbot by inspection of their gonads proved quite difficult. Differences between gonads of different "sexes" were subtle. Since these data were collected long after the spawning season had ended (February - April), there was no chance to verify the accuracy of our determinations.

Only enough information was collected to estimate the parameters in the length-weight relationships for Paxson and Harding Lakes (Figure 9). Data from other populations were too few or were of too short a range to provide dependable estimates (see Appendix Figure 13). Under these circumstances, the algorithm used to estimate parameters could converge only to a broad range of estimates of near equal predictive qualities or could not converge at all.

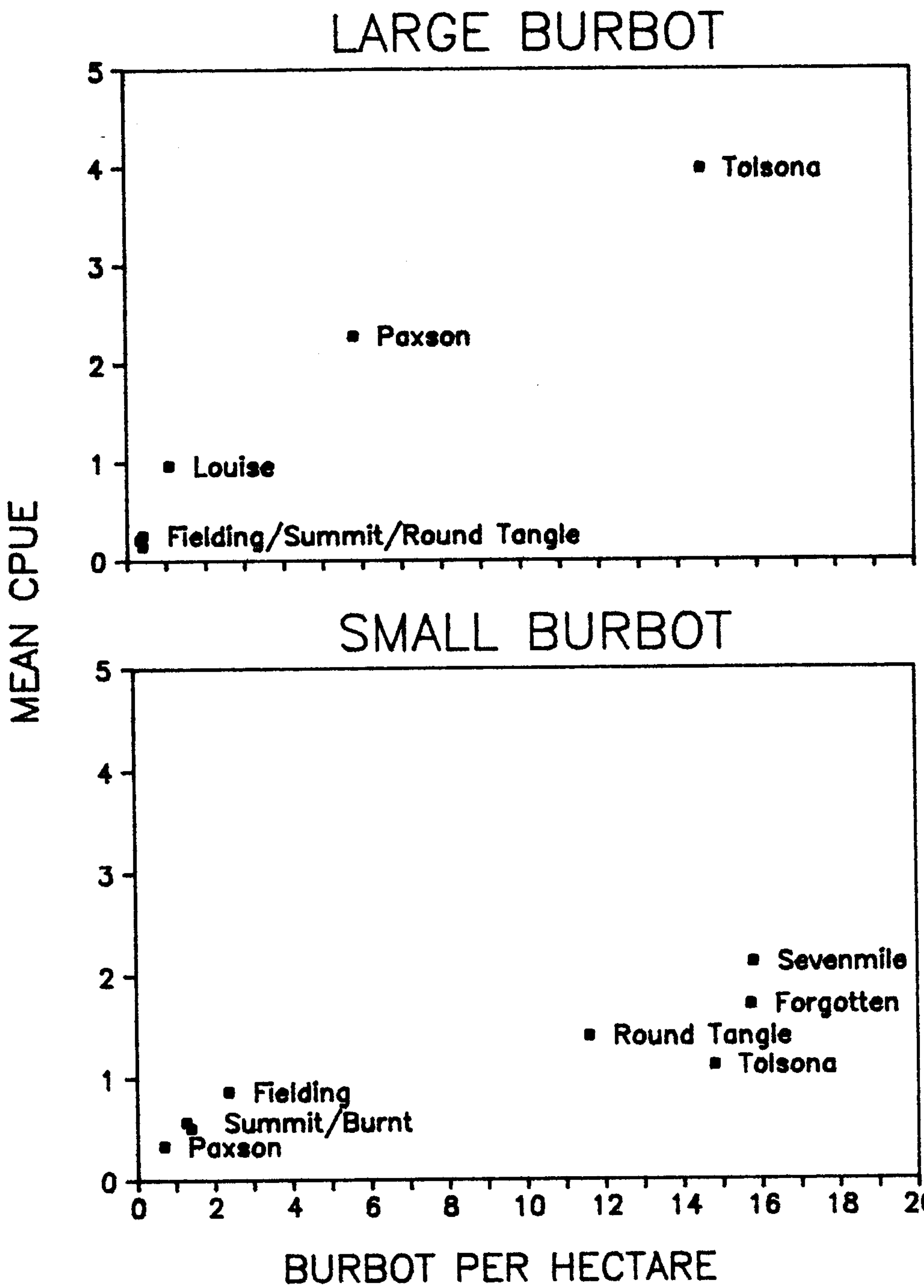

Figure 6. Mean CPUE and estimated density of small (<450 mm TL) and large ($\geq$450 mm TL) burbot in several lakes in Interior Alaska in 1986.

Table 7. Mean lengths (mm TL) of burbot measured during sampling events in Fielding, Forgotten, Glacier, Harding, Landlock Tangle, Lake Louise, Moose, Paxson, Round Tangle, Sevenmile, Shallow Tangle, Summit, Susitna, Tee, Tolsona, Tyone, Upper Tangle, and West Twin Lakes in 1986.

		First Event			Second Event			Both Events
Lake	Statistic	Small	Large[1]	All	Small	Large	All	Large
Fielding	Mean	380	521	414	388	516	425	519
	SE	3	12	5	3	10	6	8
	Samples	184	59	243	127	51	178	110
Forgotten	Mean	382	496	386	376	462	380	475
	SE	4	21	4	4	7	4	11
	Samples	63	2	65	60	3	63	5
Glacier	Mean	327		327				
	SE	10		10				
	Samples	19		19				
Harding	Mean	337	532	434				
	SE	9	13	12				
	Samples	57	57	114				
Landlock Tangle	Mean	333	525	379				
	SE	10	21	15				
	Samples	38	12	50				
Louise	Mean	395	592	562	375	562	521	575
	SE	7	5	6	6	4	5	3
	Samples	38	218	256	81	289	370	507
Moose	Mean	419	498	462	414	499	466	498
	SE	1	2	1	3	3	3	2
	Samples	692	844	1536	118	181	299	1,025
Paxson	Mean	404	587	569	362	599	554	592
	SE	5	3	4	6	4	6	3
	Samples	50	462	512	79	344	423	806
Round Tangle	Mean	369	479	385	372	470	380	475
	SE	4	5	5	5	6	6	4
	Samples	115	20	135	60	12	72	32

-Continued-

Table 7. Mean lengths (mm TL) of burbot measured during sampling events in Fielding, Forgotten, Glacier, Harding, Landlock Tangle, Lake Louise, Moose, Paxson, Round Tangle, Sevenmile, Shallow Tangle, Summit, Susitna, Tee, Tolsona, Tyone, Upper Tangle, and West Twin Lakes in 1986 (continued).

		First Event			Second Event			Both Events
Lake	Statistic	Small	Large	All	Small	Large	All	Large
Sevenmile	Mean	324		324	325		325	
	SE	5		5	3		3	
	Samples	39		39	113		113	
Shallow Tangle	Mean	328	479	332	325	490	331	483
	SE	6	5	6	8		9	5
	Samples	73	2	75	31	1	32	3
Summit	Mean	389	506	417	382	501	413	503
	SE	3	8	5	3	6	5	5
	Samples	153	49	202	176	62	238	111
Susitna	Mean	383	565	471	362	534	419	547
	SE	9	13	13	6	8	8	7
	Samples	36	34	70	94	47	141	81
Tee	Mean	301	624	501				
	SE	36	34	43				
	Samples	8	13	21				
Tolsona	Mean	411	501	481	412	497	481	499
	SE	3	2	2	3	2	2	1
	Samples	152	528	680	110	477	587	1005
Tyone	Mean	407	521	504	389	512	450	517
	SE	9	5	6	4	6	6	4
	Samples	19	111	130	82	82	164	193
Upper Tangle	Mean	352	521	374	342	493	370	504
	SE	9	15	12	10	10	12	9
	Samples	41	6	47	39	9	48	15
West Twin	Mean	407	512	478				
	SE	5	3	5				
	Samples	58	122	180				

[1] Large burbot are 450 mm TL long or longer while small burbot are shorter.

Table 8. Estimated mean length at age for burbot in Fielding, Harding, Moose, Paxson, Summit, Tolsona, Tyone, and West Twin Lakes and Lake Louise in 1986.

	Fielding				Harding				Louise				Moose			
Age	n[1]	M[2]	F[3]	Both	n	M	F	Both	n	M	F	Both	n	M	F	Both
0	16	107	106	106	0				0				0			
1	20	173	153	164	0				0				0			
2	15	231	210	223	0				4	315	297	306	1		278	278
3	2		250	250	10	382	366	372	8	334	362	348	1		345	345
4	9	288	271	278	9	420	389	417	11	394	373	385	5		386	386
5	6		324	324	9	442	464	456	23	434	423	429	6		424	424
6	10	389	379	386	7	518	533	524	12	466	474	469	9	443	514	506
7	20	435	459	447	1	632		632	17	510	525	517	4		501	501
8	14	474	449	465	1	776		776	13	574	536	544	1		703	703
9	12	523	520	522	1		734	734	9	629	570	583	0			
10	1	407		407	0				2		595	595	0			
11	2	500	592	546	1		735	735	1		631	631	0			
12	2	756	570	663	1	760		760	0				0			
13	0				1		893	893	1		848	848	0			
14	1		871	871	0				0				0			
15	0				0				0				0			
16	0				0				0				0			
17	0				0				0				0			
18	0				0				0				0			
All	130	331	323	327	41	475	491	482	101	453	485	470	27	443	458	458

-Continued-

Table 8. Estimated mean length at age for burbot in Fielding, Harding, Moose, Paxson, Summit, Tolsona, Tyone, and West Twin Lakes and Lake Louise in 1986 (continued).

	Paxson				Summit				Tolsona				Tyone				West Twin			
Age	n	M	F	Both	n	M	F	Both	n	M	F	Both	n	M	F	Both	n	M	F	Both
0	0				0				0				0				0			
1	0				0				0				0				0			
2	0				0				0				0				1		270	270
3	0				0				0				0				2	465	335	400
4	7	349	364	358	0				3	378	340	365	3	278	293	288	4	366	417	391
5	8	443	409	422	2	330	320	325	5	411	385	401	3	331	371	358	25	432	426	429
6	14	423	482	448	11	389	364	371	2	445		445	1		395	395	26	469	446	456
7	15	509	517	514	7	419	417	418	5	460	456	457	2	431	345	388	21	463	500	486
8	20	510	549	531	3	404	648	485	11	536	506	522	2		438	438	8	504	523	513
9	13	601	597	599	0				0				2		483	483	7	524	514	521
10	9	610	615	613	0				0				5	588	510	525	0			
11	11	644	627	635	0				0				3		573	573	1		570	570
12	8	689	691	691	0				0				0				0			
13	9	675	697	685	0				0				0				0			
14	1		685	685	0				0				0				0			
15	0				0				0				0				0			
16	0				0				0				0				0			
17	0				0				0				0				0			
18	0				0				0				0				0			
All	115	539	558	549	23	396	396	396	26	468	455	462	21	407	451	443	95	462	459	460

[1] Sample size.
[2] Males.
[3] Females.

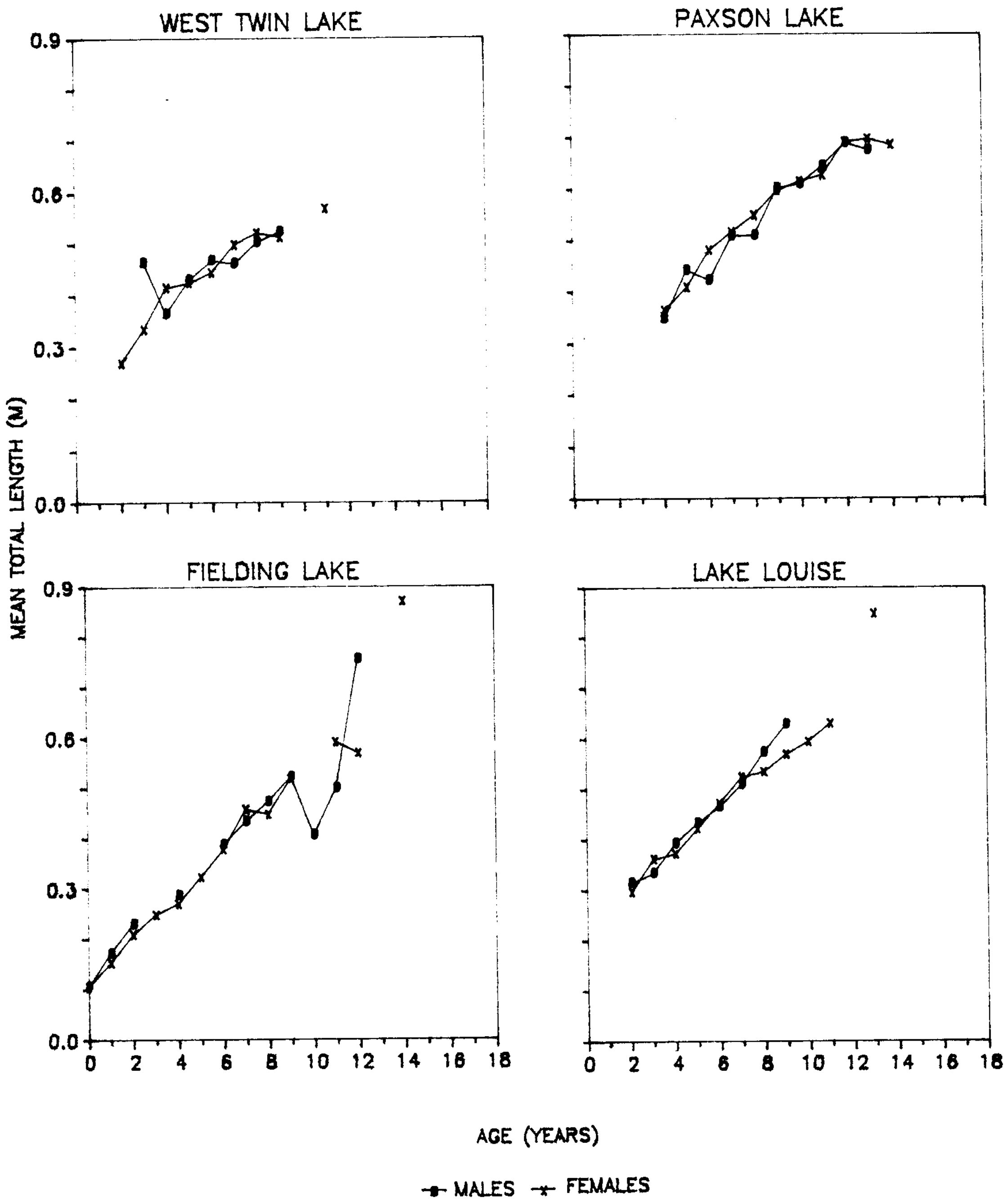

Figure 7. Estimated mean length at age of male and female burbot in West Twin, Paxson, and Fielding Lakes and Lake Louise. Data were collected in 1986 for all populations and in 1982-1985 for the population in Fielding Lake as well.

Table 9. Estimated sex composition of burbot in Fielding, Harding, Moose, Paxson, Summit, Tolsona, Tyone, and West Twin Lakes and Lake Louise in 1986.

	Fielding				Harding				Louise				Moose				Paxson			
Age	n[1]	M[2]	F[3]	SE[4]	n	M	F	SE	n	M	F	SE	n	M	F	SE	n	M	F	SE
0	16	0.44	0.56	0.13	0				0				0				0			
1	20	0.55	0.45	0.11	0				0				0				0			
2	15	0.60	0.40	0.13	0				4	0.50	0.50	0.29	1	0.00	1.00		0			
3	2	0.00	1.00	0.00	10	0.40	0.60	0.16	8	0.50	0.50	0.19	1	0.00	1.00		0			
4	9	0.44	0.56	0.18	9	0.89	0.11	0.11	11	0.55	0.45	0.16	5	0.00	1.00		7	0.43	0.57	0.20
5	6	0.00	1.00	0.00	9	0.33	0.67	0.17	23	0.52	0.48	0.11	6	0.00	1.00		8	0.38	0.62	0.18
6	10	0.70	0.30	0.15	7	0.57	0.43	0.20	12	0.58	0.42	0.15	9	0.11	0.89	0.11	14	0.57	0.43	0.14
7	20	0.50	0.50	0.11	1	1.00	0.00		17	0.53	0.47	0.12	4	0.00	1.00		15	0.40	0.60	0.13
8	14	0.64	0.36	0.13	1	1.00	0.00		13	0.23	0.77	0.12	1	0.00	1.00		20	0.45	0.55	0.11
9	12	0.42	0.58	0.15	1	0.00	1.00		9	0.22	0.78	0.15	0				13	0.54	0.46	0.14
10	1	1.00	0.00		0				2	0.00	1.00		0				9	0.44	0.56	0.18
11	2	0.50	0.50	0.50	1	0.00	1.00		1	0.00	1.00		0				11	0.45	0.55	0.16
12	2	0.50	0.50	0.50	1	1.00	0.00		0				0				8	0.25	0.75	0.16
13	0				1	0.00	1.00		1	0.00	1.00		0				9	0.56	0.44	0.18
14	1	0.00	1.00		0				0				0				1	0.00	1.00	
15	0				0				0				0				0			
16	0				0				0				0				0			
17	0				0				0				0				0			
18	0				0				0				0				0			
All	130	0.50	0.50	0.04	41	0.54	0.46	0.08	101	0.45	0.55	0.05	27	0.04	0.96	0.04	115	0.45	0.55	0.05

-Continued-

Table 9. Estimated sex composition of burbot in Fielding, Harding, Moose, Paxson, Summit, Tolsona, Tyone, and West Twin Lakes and Lake Louise in 1986 (continued).

	Summit				Tolsona				Tyone				West Twin			
Age	n	M	F	SE	n	M	F	SE	n	M	F	SE	n	M	F	SE
0	0				0				0				0			
1	0				0				0				0			
2	0				0				0				1	0.00	1.00	
3	0				0				0				2	0.50	0.50	0.50
4	0				3	0.67	0.33	0.33	3	0.33	0.67	0.33	4	0.50	0.50	0.29
5	2	0.50	0.50	0.50	5	0.60	0.40	0.24	3	0.33	0.67	0.33	25	0.48	0.52	0.10
6	11	0.27	0.73	0.14	2	1.00	0.00		1	0.00	1.00		26	0.42	0.58	0.10
7	7	0.43	0.57	0.20	5	0.40	0.60	0.24	2	0.50	0.50	0.50	21	0.38	0.62	0.11
8	3	0.67	0.33	0.33	11	0.55	0.45	0.16	2	0.00	1.00		8	0.50	0.50	0.19
9	0				0				2	0.00	1.00		7	0.71	0.29	0.19
10	0				0				5	0.20	0.80	0.20	0			
11	0				0				3	0.00	1.00		1	0.00	1.00	
12	0				0				0				0			
13	0				0				0				0			
14	0				0				0				0			
15	0				0				0				0			
16	0				0				0				0			
17	0				0				0				0			
18	0				0				0				0			
All	23	0.39	0.61	0.10	26	0.58	0.42	0.10	21	0.19	0.81	0.09	95	0.45	0.55	0.05

1 Sample size.
2 Males.
3 Females.
4 Standard Error.

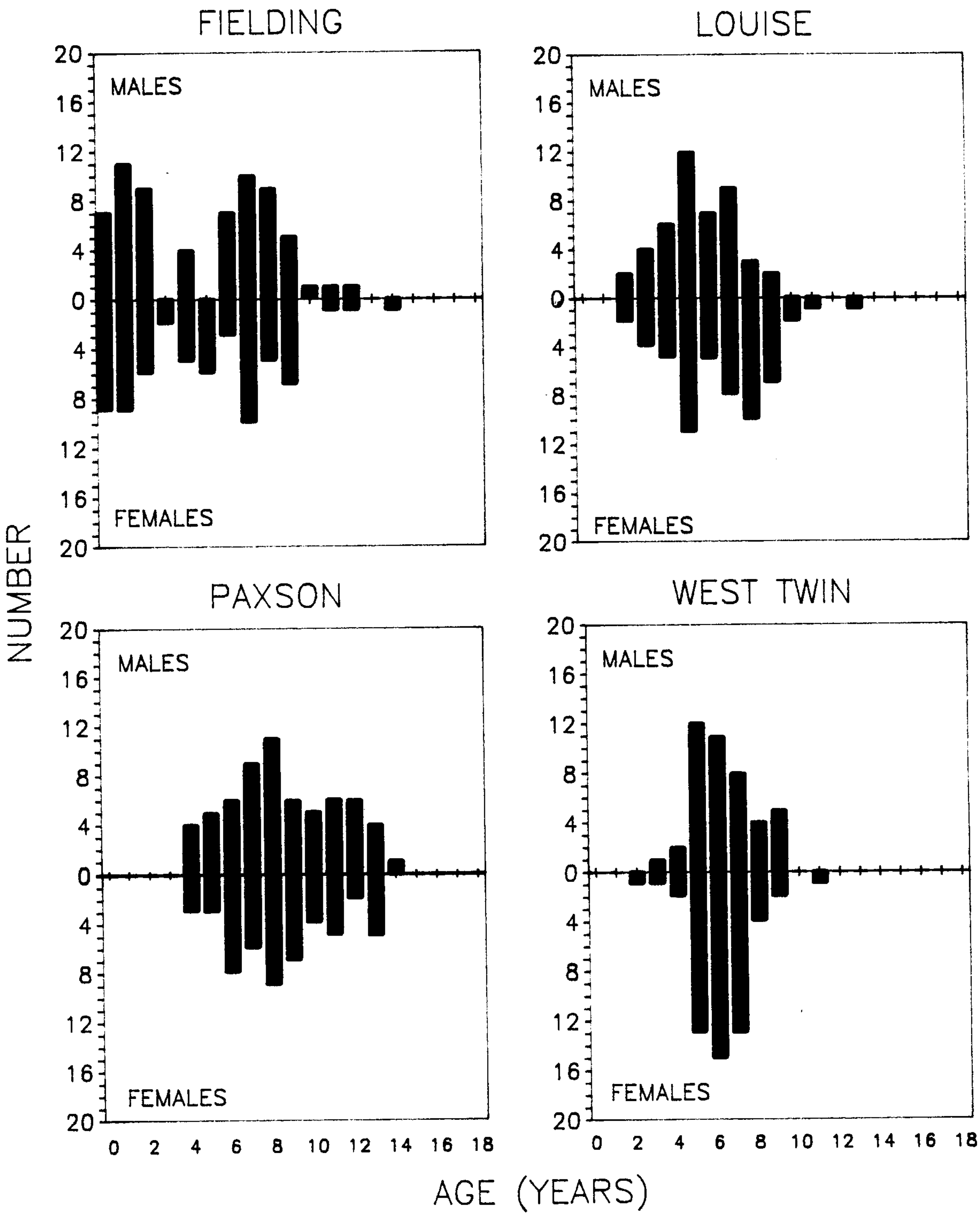

Figure 8. Number of male and female burbot by age in samples from West Twin, Paxson, and Fielding Lakes and Lake Louise. Data were collected in 1986 for all populations and in 1982-1985 for the population in Fielding Lake as well.

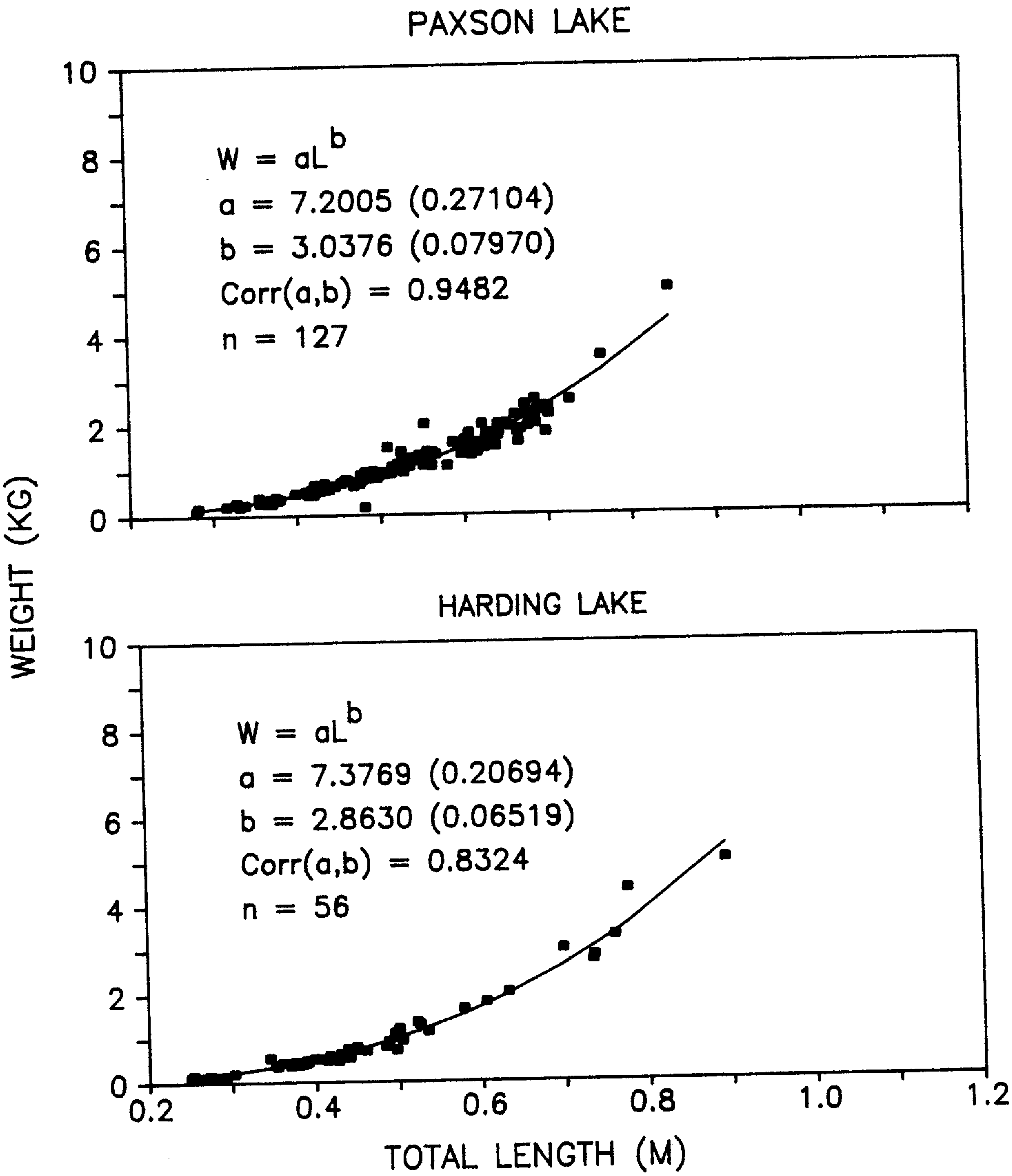

Figure 9. Estimates of parameters in the length-weight relationships for burbot in Paxson and Harding Lakes in 1986. Values in parentheses are standard errors of estimates. Data were collected in 1986.

Big vs. Small Hoop Traps

During the third sampling event in Paxson Lake, more burbot were caught in small traps than in big traps. Of the 120 sets in this experiment, 60 were with big traps and 60 with small. Two hundred twenty-four burbot were captured, 101 in the big traps and 123 in the small traps. The average catch per set was 1.68 and 2.05 burbot per set for big and small traps, respectively. The frequency of "zero catches" was much greater for big traps than small (Figure 10); also, the catch in big traps includes one set with 10 burbot. The differences in the frequency of catches in big and small traps is significantly different (χ^2=9.97, 0.025<P<0.0.5, df=4).

The burbot caught in big and small traps were of similar sizes (Figure 11). Length distributions of burbot caught in both sizes of traps are bimodal with modes at 301-350 mm TL and 601-650 mm TL; these length distributions are not significantly different (Kolmogorov-Smirnov Two-Sample Test Statistic D = 0.09, P>0.8).

DISCUSSION

With any new project, a certain amount of "shakedown" usually occurs. In 1986, Moose and Forgotten Lakes were sampled first in early June. Data were recorded for the population of burbot in Moose Lake such that catches of large and small burbot could not be calculated. Since Moose Lake contained many small burbot and small burbot are not fully recruited to hoop traps, an estimate of mean CPUE for burbot of all sizes would most probably have been highly biased. Therefore, mean CPUE for the first sampling event in Moose Lake was not estimated. And since mean CPUE tended to drop by half in other populations when chronologically sampled as was the population in Moose Lake, the mean CPUE of large and small burbot calculated for the second sampling event was not compared to estimated density from the first event. During the first sampling event in Forgotten Lake, 87 fish were caught. But of these 87, 79 were caught in sets of only 24 hours and then released (four sets) or were caught in sets with no concomitant information on time of soak (five sets). Only eight fish were caught in the remaining six sets. Obviously, with information on soak times and stricter adherence to sampling design on these nine sets, the mean CPUE for Forgotten Lake would have been much higher. These problems were not repeated on any other sampling events in any other lake.

The accuracy of abundance estimates from the mark-recapture experiments are predicated on certain conditions (Ricker 1975): 1)equal probability of capture for all burbot during at least one sampling event or complete dispersal of tagged burbot throughout the population, 2)ability to identify marked fish, 3)no recruitment between sampling events, and 4)equal probability of survival and capture of marked and unmarked fish. In all our sampling events, sampling effort and subsequently tagged fish were spread throughout each lake. Therefore, the first condition need hold only for local areas, not for the whole lake, for our estimates to be unbiased.

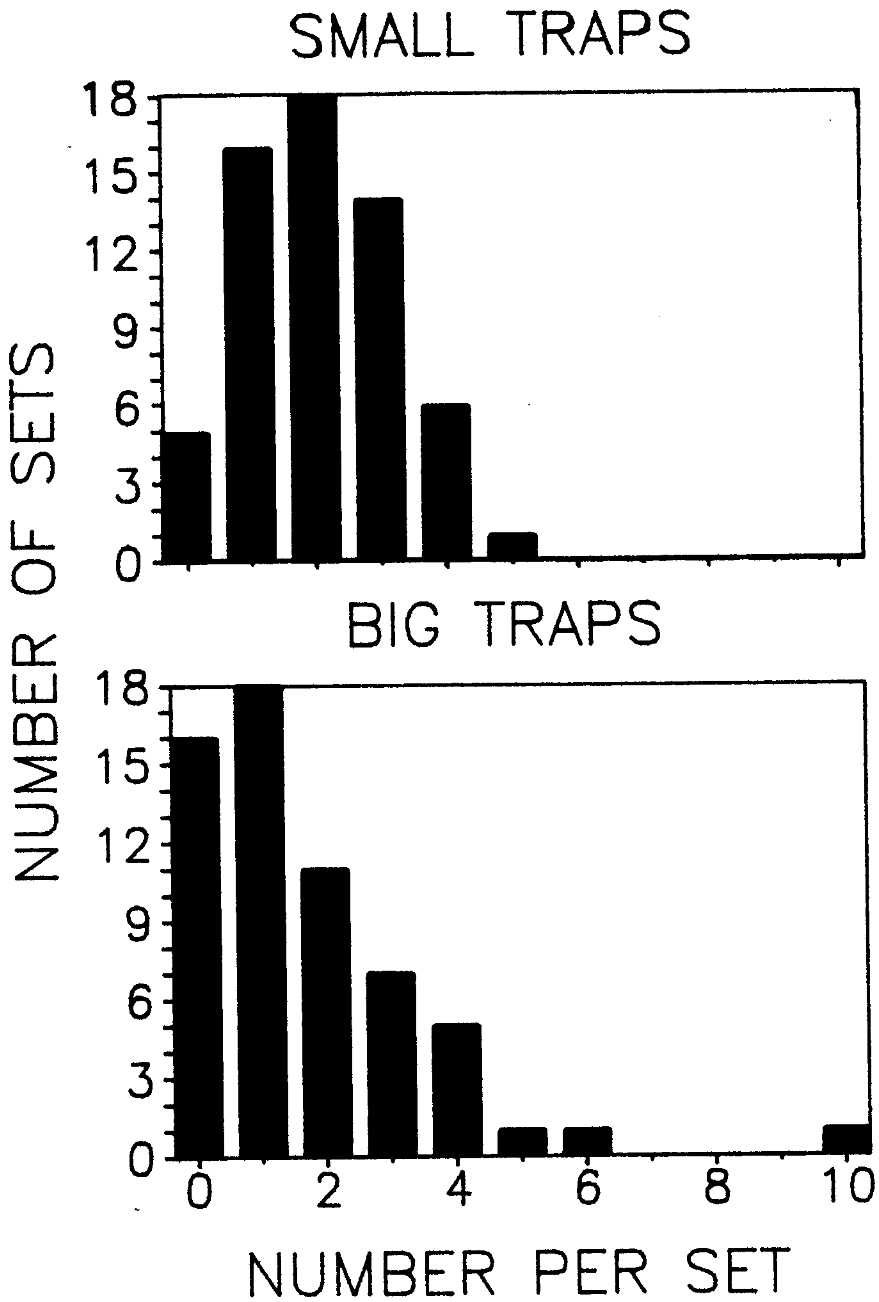

Figure 10. Frequency of sets by catch in big and small hoop traps during the third sampling event in Paxson Lake in 1986.

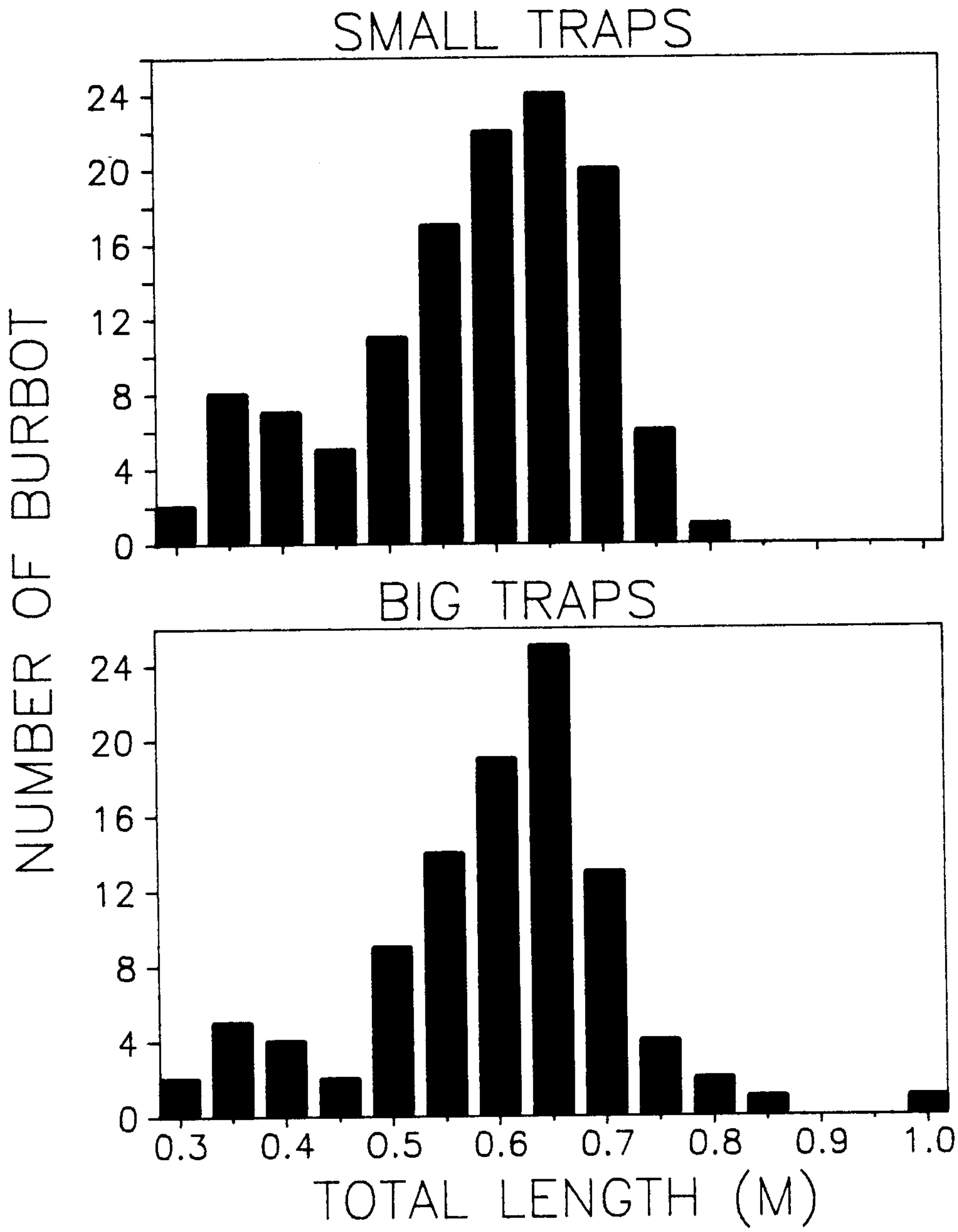

Figure 11. Length frequency of burbot caught in big and small hoop traps during the third sampling event in Paxson Lake in 1986.

Also, the dispersal of burbot throughout all depths in the summer would promote the dispersal of fish tagged in early summer. And calculation of separate estimates for large and small burbot negated problems with different gear selectivity for burbot of different sizes. As for the second condition, very few burbot with fin clips and no tags were found during the second sampling events. As for the third condition, sampling events were often a few weeks apart so there was little time for recruitment through growth. When we looked for recruitment between sampling events, no recruitment was found. Evaluation of our meeting the fourth condition will have to wait until next year. Comparison of proportions of marked burbot (after corrections for recruitment) among years will indicate if burbot become trap shy and do not overcome it by the length of time between sampling events in 1986.

Precision of estimates of mean CPUE suffered somewhat when systematic designs were stratified. In those cases when a transect was "stranded" with only one set after post stratification, no estimate of "within" transect variance existed for that transect, and it was excluded from the analysis. Enough of these instances during a sampling event would drop the degrees of freedom in stratified designs to the point that stratified estimates might no longer be more precise that unstratified ones. This is one possible reason why more stratified estimates were not selected over their stratified "competitors" in this analysis.

Adjusting CPUE by soak times introduced some small bias into estimates of mean CPUE. When a set is not soaked for exactly 48 hours, division of its catch by the time of set will not adjust "zero" catches but will adjust larger catches. Therefore, lakes with many burbot will have "better" adjustment than will lakes with fewer burbot and more "zero" catches. As long as soak times are close to 48 hours, this bias should be minimal. However, adjusting catches for longer or shorter soak times than a few hours would introduce significant bias. This is one reason for not adjusting the catches from one-day soak times in Forgotten Lake as mentioned above.

And finally, the small hoop traps are preferred over big traps for catching burbot. For populations like that in Paxson Lake, both traps have the same size selectivity and catch burbot at about the same rate with the small traps doing somewhat better. Since the small traps are easier to handle and cheaper to buy, they are preferred.

ACKNOWLEDGEMENTS

We wish to thank Doug Vincent-Lang for his excellent assistance with estimates, tables, and figures on age and length of burbot. We wish to thank Jay D. Johnson, Dave Waldo, Doug Reed, Jeff Barnard, and Richard Erving whose field work made this project possible. We are grateful to John H. Clark and Paul Krasnowski for their support, advice, and direction. And lastly, we thank the U.S. Fish and Wildlife Service for partially funding this work.

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APPENDICES

Description of Lakes

BURNT LAKE (62°07′ W, 146°6′ W) is located 1 km east of the road to Lake Louise 10 km from the Glenn Highway. Burnt Lake is 24 ha with a maximum depth of 10 m and an elevation of 854 m. There are no cabins or public recreational facilities, and this lake has relatively little fishing pressure. Burnt Lake contains Arctic grayling, *Thymallus arcticus* (Pallas), and burbot.

DEADMAN LAKE (64°51′ N, 149°58′ W) is a remote fly-in lake 177 km southwest of Fairbanks. The lake is 207 ha with a maximum depth of 21 m and an elevation of 138 m. Deadman Lake has northern pike, *Esox lucius* Linnaeus; humpback whitefish; *Coregonus pidschian* (Gmelin); and burbot.

FIELDING LAKE (63°10′ N, 145°42′ W) is accessible by road 3 km southwest of the Richardson Highway. Fielding Lake is 538 ha with a maximum depth of 24 m and an elevation of 906 m. Campground facilities and a lodge operated during the summer are located at the mouth of the outlet, also 15 to 20 recreational cabins are located along the south shore. Fielding Lake contains Arctic grayling; lake trout, *Salvelinus namaycush* (Walbaum); round whitefish, *Prosopium cylindraceum* (Pallas); and burbot.

FORGOTTEN LAKE (62°08′ W, 146°27′ W) is directly accessible from the road to Lake Louise 12 km from the Glenn Highway. Forgotten Lake is 6 ha with a maximum depth of 6 m and an elevation of 915 m. No cabins or public recreational facilities are at the lake, and there is relatively little fishing pressure. Forgotten Lake has Arctic grayling and burbot.

GLACIER LAKE (63°07′ N, 164°15′ W) is a semi-remote lake located 3 km north of the Denali Highway. The lake is accessible by trail or all terrain vehicle. Glacier Lake is 172 ha with a maximum depth of 26 m and an elevation of 1,124 m. No habitable dwellings exist on this glacially colored lake. Glacier Lake has populations of lake trout, Arctic grayling, round whitefish, and burbot.

HARDING LAKE (64°25′ N, 146°50′ W) is accessible by road, located 72 km southeast of Fairbanks along the Richardson Highway. Harding Lake is 1,000 ha with a maximum depth of 47 m and an elevation of 218 m. Campground facilities and boat launch are located on the west shore of the lake; recreational cabins and houses are located along the shoreline. Harding Lake contains indigenous species of northern pike; least cisco, *Coregonus sardinella* Valenciennes; slimy sculpin, *Cottus cognatus* Richardson; and burbot. Transplanted species include lake trout; rainbow trout, *Salmo gairdneri* Richardson; Arctic grayling; and coho salmon, *Oncorhynchus kisutch* (Walbaum).

LAKE LOUISE (62°20′ N, 146°30′ W) is the largest lake in a three-lake system that is accessible by the Glenn Highway on a 25 km gravel road.

Lake Louise is 6,519 ha with maximum depth of 51 m and an elevation of 720 m. A state campground with boat launch is available. Four lodges are found along the south end of the lake, and numerous cabins are located around the shore. Lake Louise supports year round fishing for lake trout, burbot, and other species.

LANDLOCK TANGLE LAKE (63°00′ N, 146°03′ W) is located south of Upper Tangle Lake and is accessible by foot over a 1 km portage. Landlock Tangle Lake is 219 ha with a maximum depth of 36 m and an elevation of 875 m. Landlock Tangle Lake has Arctic grayling; lake trout; round whitefish; burbot; and longnose suckers, *Catostomus catostomus* (Forster).

MOOSE LAKE (62°07′ N, 146°05′ W) is accessible from Tolsona Lake by all-terrain vehicle on a 1 km trail from the north end of Tolsona Lake. Moose Lake is 130 ha with a maximum depth of 6 m and an elevation of 625 m. There are four cabins located along the lake shore and no public recreational facilities. Moose Lake receives fishing pressure largely during the winter months for burbot. Moose Lake contains burbot, Arctic grayling, longnose suckers, and rainbow trout.

PAXSON LAKE (62°50′ N, 145°35′ W) is directly accessible from the Richardson Highway 8 km south of Paxson. Paxson Lake is 1,575 ha with a maximum depth of 29 m and an elevation of 778 m. There are numerous cabins along the shore and the Bureau of Land Management maintains a public campground and boat launch. Paxson Lake is the start of a popular float trip on the Gulkana River to Sourdough. This lake is popular for its wide variety of fishing as well as hunting opportunities. Paxson Lake contains lake trout; burbot; sockeye salmon, *O. nerka* (Walbaum); Arctic grayling; round whitefish; and other species.

ROUND TANGLE LAKE (63°02′ N, 145°48′ W) is located north of the Denali Highway. Round Tangle Lake is 155 ha with a maximum depth of 29 m and an elevation of 851 m. A public boat launch, campground facilities and lodge accommodations are available through the spring and fall. During the winter months the Denali Highway is closed and the Tangle Lakes receive very little fishing pressure. Round Tangle Lake has Arctic grayling, lake trout, round whitefish, burbot, and longnose suckers.

SEVENMILE Lake (63°06′ N, 145°38′ W) is located 1 km by road from the Denali Highway. Sevenmile Lake is 34 ha with a maximum depth of 12 m and an elevation of 991 m. A public boat launch and campsites are available at the south end of the lake. Sevenmile Lake contains lake trout and burbot populations. No other species are known to exist in the lake.

SHALLOW TANGLE LAKE (63°02′ N, 145°48′ W) is located north of Round Tangle Lake. Shallow Tangle Lake is accessible by boat through Round Tangle Lake and 500 m river between the two lakes. Shallow Tangle Lake is 130 ha with a maximum depth of 24 m and an elevation of 849 m. Shallow Tangle Lake has Arctic grayling, lake trout, round whitefish, burbot, and longnose suckers.

SUMMIT LAKE (63°12′ N, 145°33′ W) is directly accessible from the Richardson Highway just 6 km north of Paxson. Summit Lake is 1,651 ha with a maximum depth of 72 m and an elevation of 979 m. Public facilities are available for launching boats only. There is one lodge and a private recreational vehicle campground along the lake. Summit Lake contains lake trout, sockeye salmon, burbot, and round whitefish.

SUSITNA LAKE (62°25′ N, 146°38′ W) is the second lake in a three-lake system and is accessible by a connecting channel of 100 m to Lake Louise. Susitna Lake is 3,816 ha with a maximum depth of 37 m and an elevation of 720 m. There are many private recreational cabins scattered along the shores of Susitna Lake, however, no commercial accommodations are present. Susitna Lake has lake trout, burbot, longnose succkers, and round whitefish.

TEE LAKE (63°48′ N, 143°53′ W) is a remote fly-in lake, located approximately 18 km from the village of Dot Lake along the Alaska Highway. Tee Lake is 162 ha with a maximum depth of 18 m and an elevation of 434 m. Only one permanent recreational structure exist on the lake. Tee Lake contains northern pike, humpback whitefish, least cisco, and burbot.

TOLSONA LAKE (62°06′ N, 146°04′ W) is accessible from the Glenn Highway. Tolsona Lake is 130 ha with a maximum depth of 4 m and an elevation of 625 m. Tolsona Lake has numerous cabins and one lodge. No public recreational facilities are available. This lake has had a popular burbot fishery in the winter in recent years. Tolsona Lake has burbot, Arctic grayling, stocked rainbow trout, longnose suckers, and other species.

TYONE LAKE (62°30′ N, 146°45′ W) is the first lake in a three-lake system system and is accessible by a connecting channel of 100 m to Susitna Lake. Tyone Lake is 389 ha with a maximum depth of 9 m and an elevation of 720 m. There is the abandoned remains of an Indian settlement (Tyone Village) and only a handful of private cabins located on this lake. Tyone Lake has Arctic grayling, lake trout, burbot, longnose suckers, and round whitefish.

UPPER TANGLE LAKE (63°00′ N, 146°04′ W) is located south of the Denali Highway but drains through 500 m long river into Round Tangle Lake. Upper Tangle Lake is 142 ha with a maximum depth of 30 m and an elevation of 868 m. There is a boat launch and campground facilities available at the mouth of this lake. Upper Tangle Lake has Arctic grayling, lake trout, round whitefish, burbot, and longnose suckers.

WEST TWIN LAKE (64°27′ N, 150°50′ W) is a remote, fly-in lake 167 km southwest of Fairbanks. West Twin Lake is 680 ha with a maximum depth of 34 m and an elevation of 228 m. A few permanent recreational cabins exist on the lake. West Twin Lake contains northern pike, humpback whitefish, burbot, and least cisco.

Appendix Table 1. Number of large (≥450 mm TL) and small (<450 mm TL) burbot caught (C), number tagged (M), and number recaptured (R) in populations for 14 lakes in Interior Alaska in 1986.

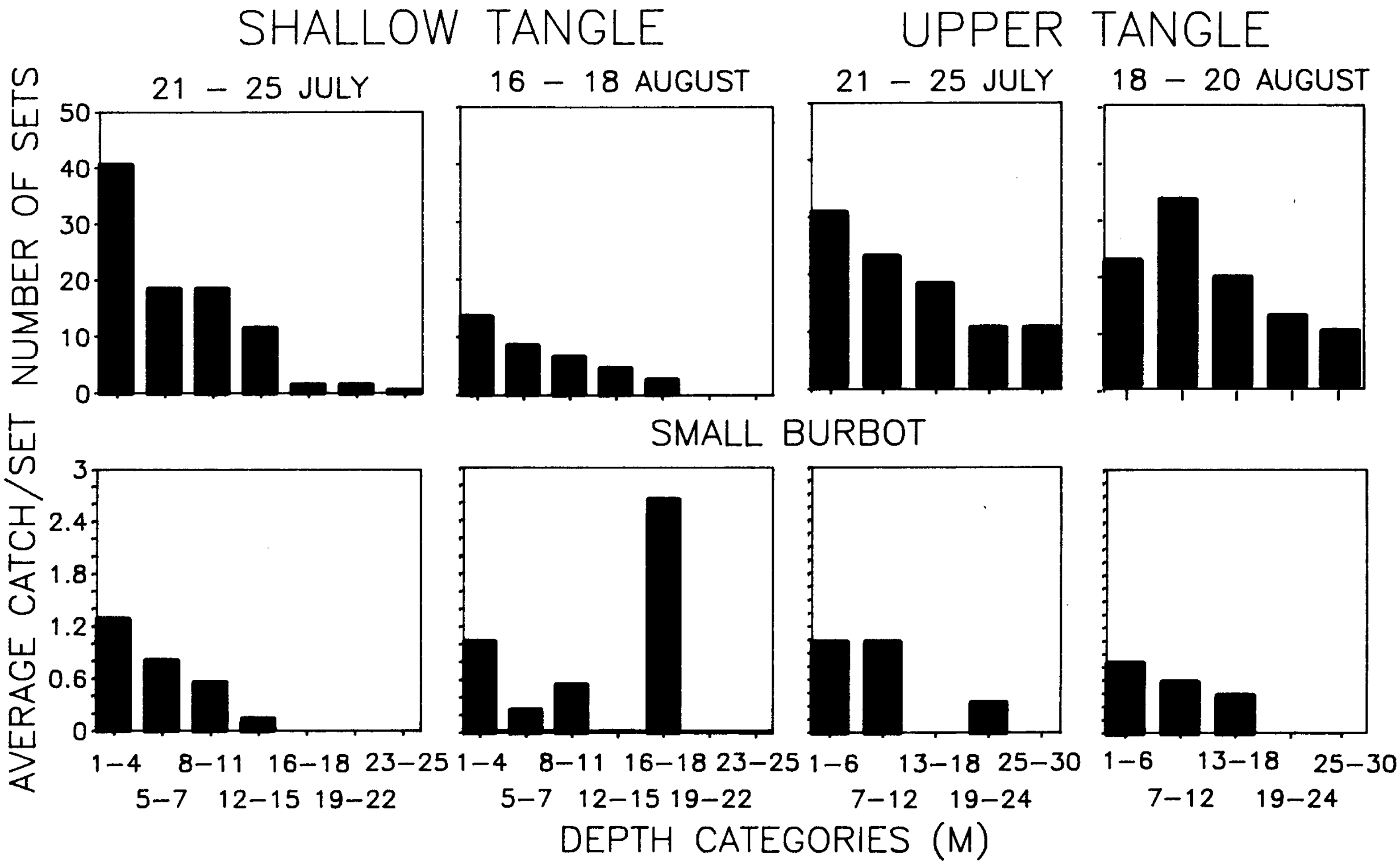
		Small Burbot			Large Burbot		
Lake	Sampling Event	C_i	M_i	R_{i-1}	C_i	M_i	R_{i-1}
Fielding[1]	4	204	184		62	59	
	5	129	128	18	49	48	13
Round Tangle	1	134	115		21	20	
	2	61	60	5	11	10	2
Shallow Tangle	1	81	73		3	2	
	2	31	31	0	1	1	1
Upper Tangle	1	46	41		7	6	
	2	39	33	0	9	9	0
Sevenmile	1	116	79		0	0	
	2	99	73	10	0	0	0
Tolsona	1	163	163		517	517	
	2	113	95	10	473	457	133
Paxson	1	85	51		537	461	
	2	82	78	3	354	350	17
	3	35	35	0	188	186	22
Summit	1	182	153		52	49	
	2	176	176	11	62	61	4
Louise	1	79	39		243	215	
	2	82	20	0	288	257	11
Susitna	1	43	36		37	34	
	2	94	75	0	47	43	0

-Continued-

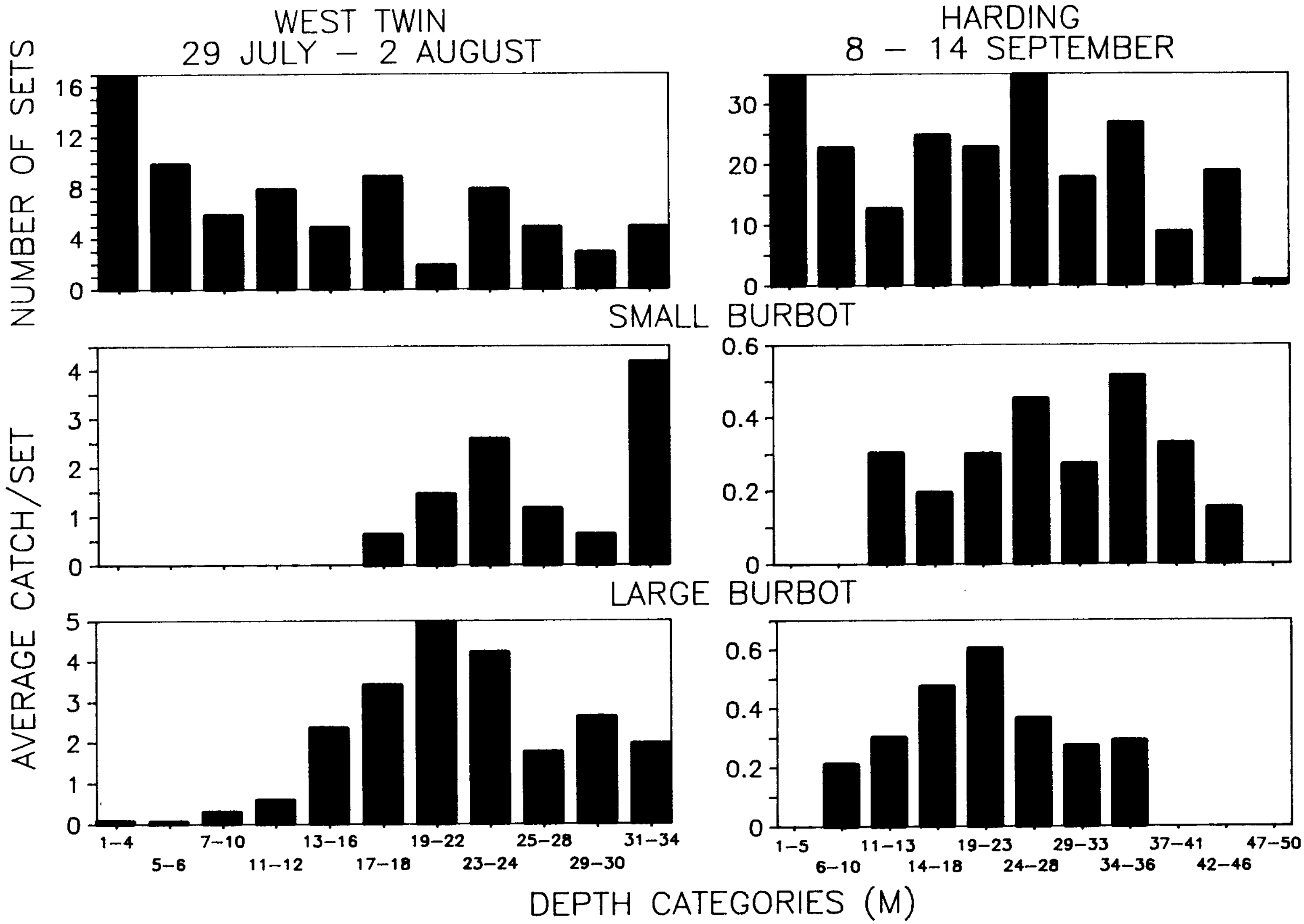
Appendix Table 1. Number of large ($\geq$450 mm TL) and small (<450 mm TL) burbot caught (C), number tagged (M), and number recaptured (R) in populations for 14 lakes in Interior Alaska in 1986 (continued).

		Small Burbot			Large Burbot		
Lake	Sampling Event	C_i	M_i	R_{i-1}	C_i	M_i	R_{i-1}
Tyone	1	20	20		110	110	
	2	83	73	0	81	70	2
Moose	1	739	724		826	813	
	2	118	118	23	181	181	84
Burnt	1	29	20		5	4	
	2	15	15	9	2	1	1
Forgotten	1	65	62		2	2	
	2	62	48	34	3	1	2
Deadman	1	0	0		1	1	
Glacier	1	19	18		0	0	
Harding	1	59	53		55	52	
Tee	1	8	8		13	13	
West Twin	1	60	11		120	73	
Landlock Tangle	1	38	35		12	12	

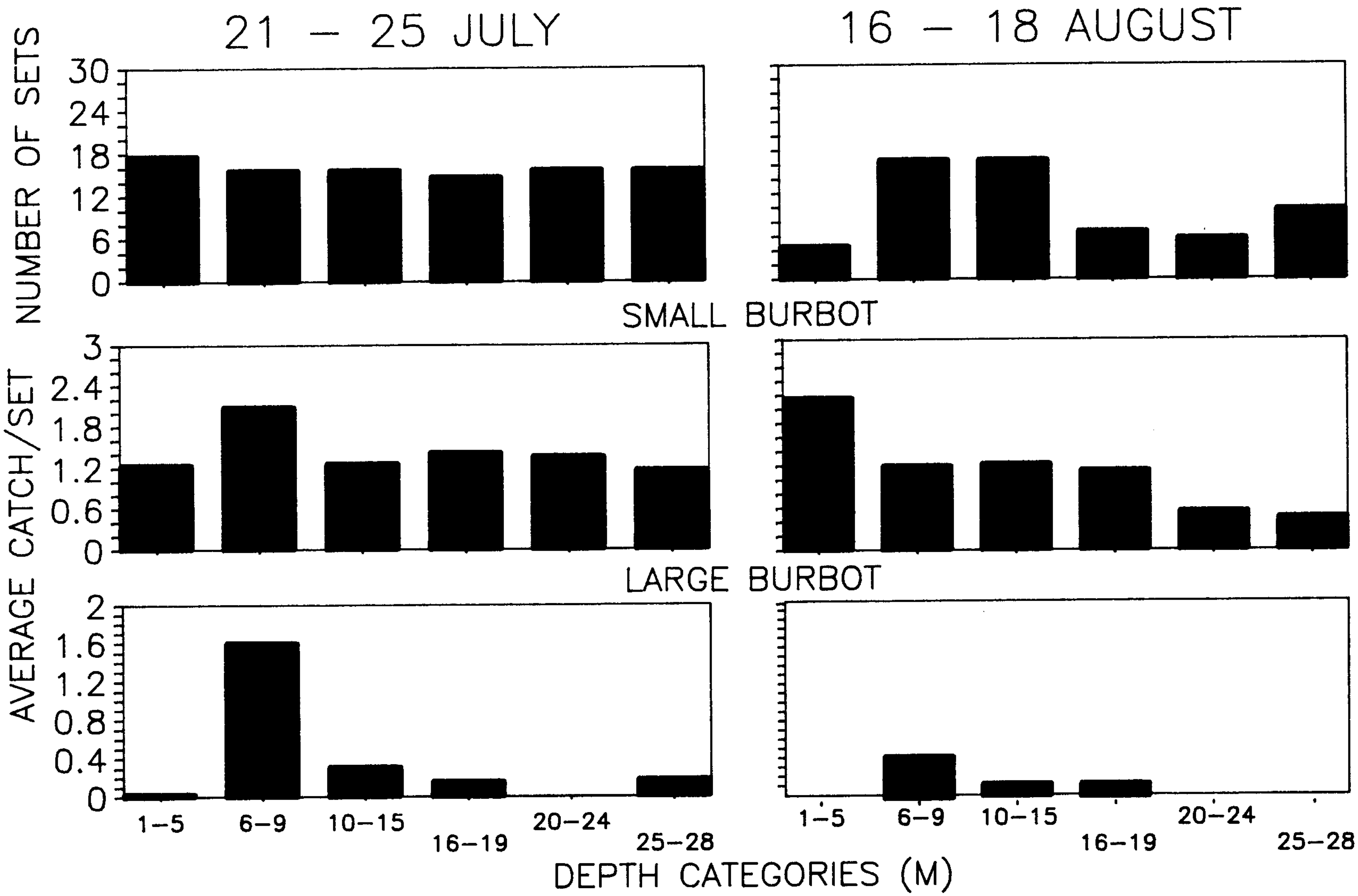
[1] The first through third sampling events in Fielding Lake occurred in 1985. Of the 129 small and 49 large burbot caught during the fifth event, 15 and 9 were tagged in 1985 but were not recaptured during the fourth sampling event, respectively. Of these last large nine fish, four were small fish in 1985 and five were large.



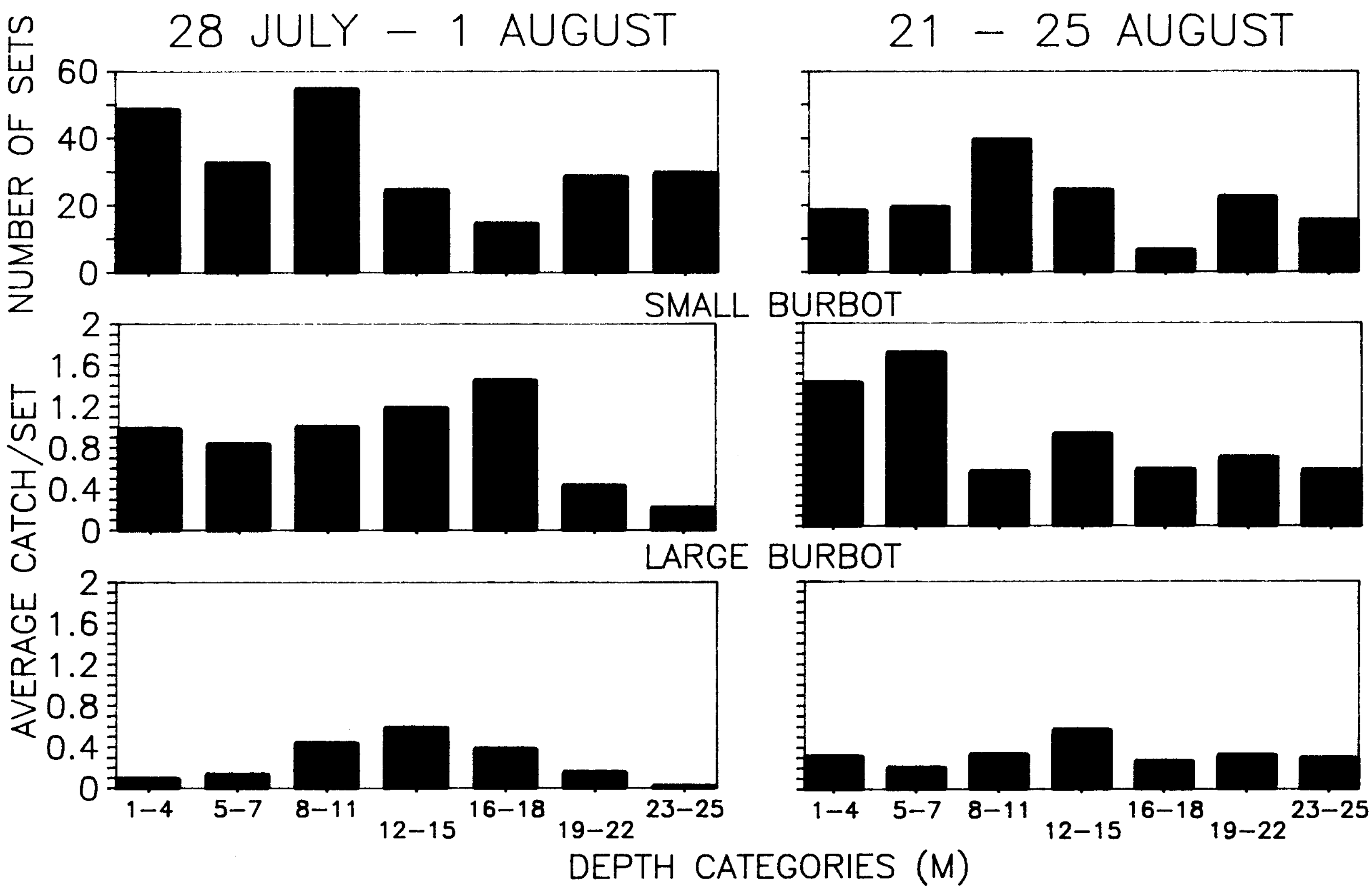
Appendix Figure 1. Frequency of sets by depth and average catch by depth of small (<450 mm TL) for the sampling events in Shallow and Upper Tangle Lakes in 1986.



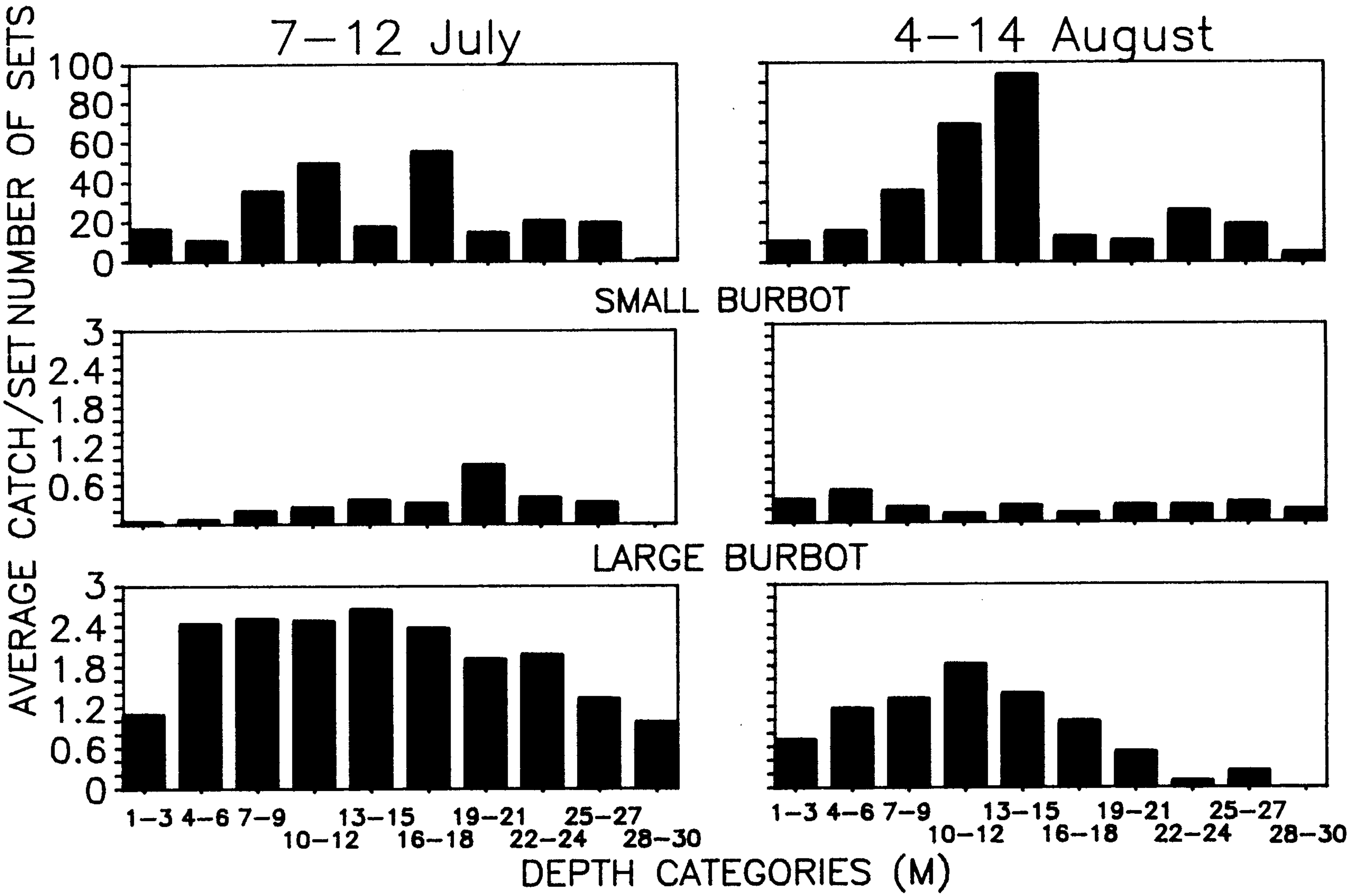
Appendix Figure 2. Frequency of sets by depth and average catch by depth of small (<450 mm TL) and large (≥450 mm TL) burbot for the sampling events in West Twin and Harding Lakes in 1986.



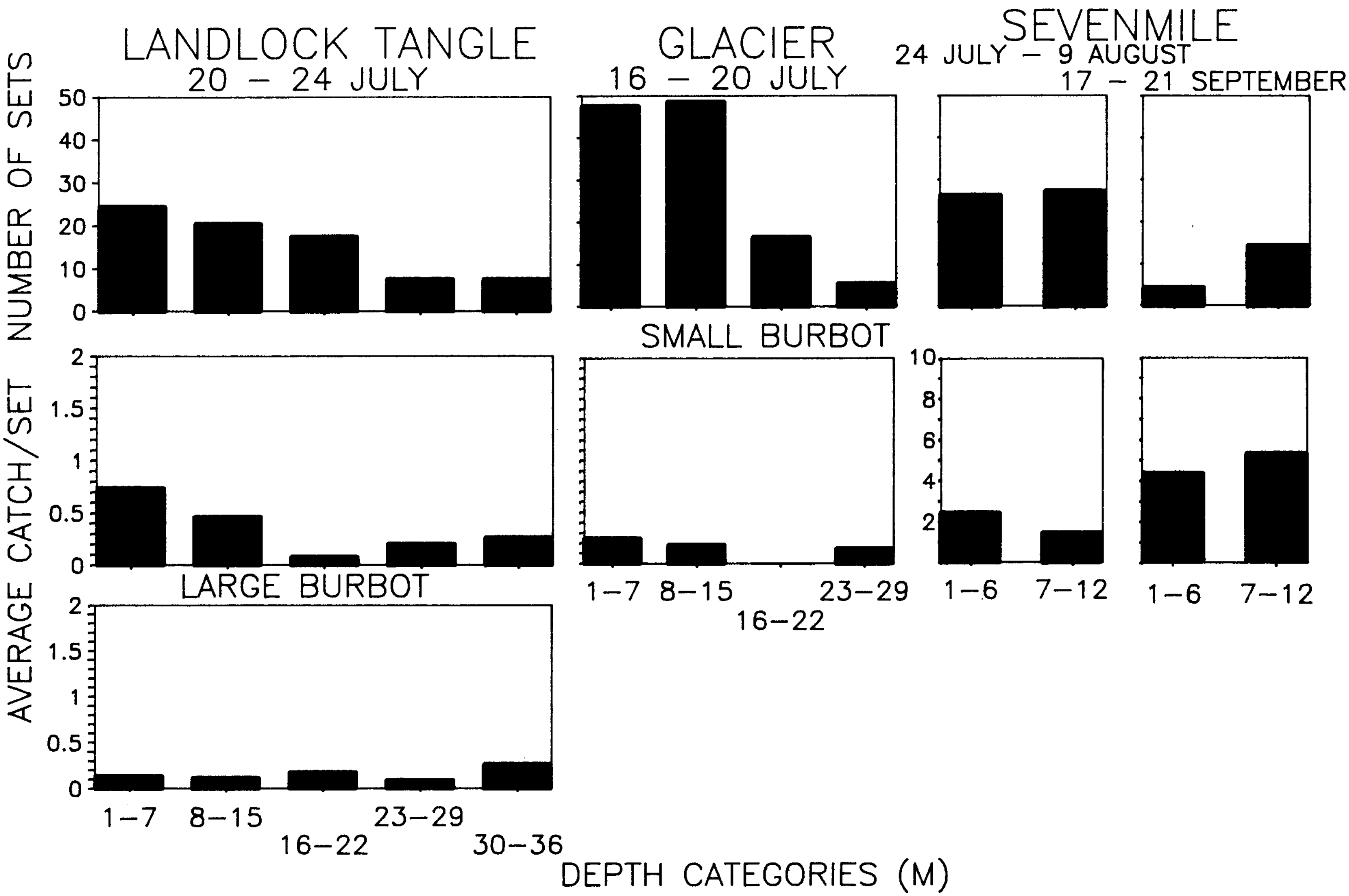
Appendix Figure 3. Frequency of sets by depth and average catch by depth of small (<450 mm TL) and large (≥450 mm TL) burbot for the sampling events in Round Tangle Lake in 1986.



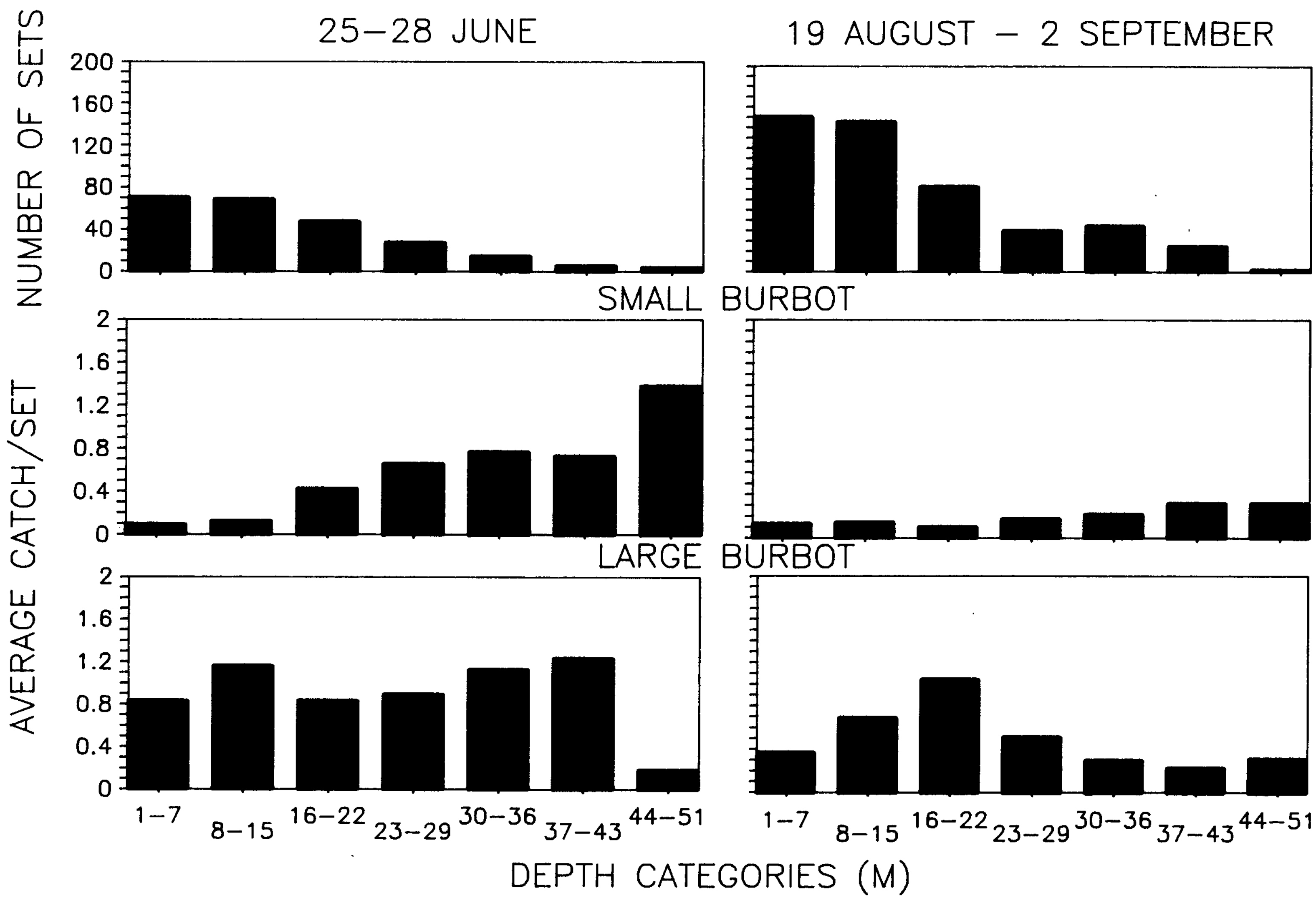
Appendix Figure 4. Frequency of sets by depth and average catch by depth of small (<450 mm TL) and large (≥450 mm TL) burbot for the sampling events in Fielding Lake in 1986.



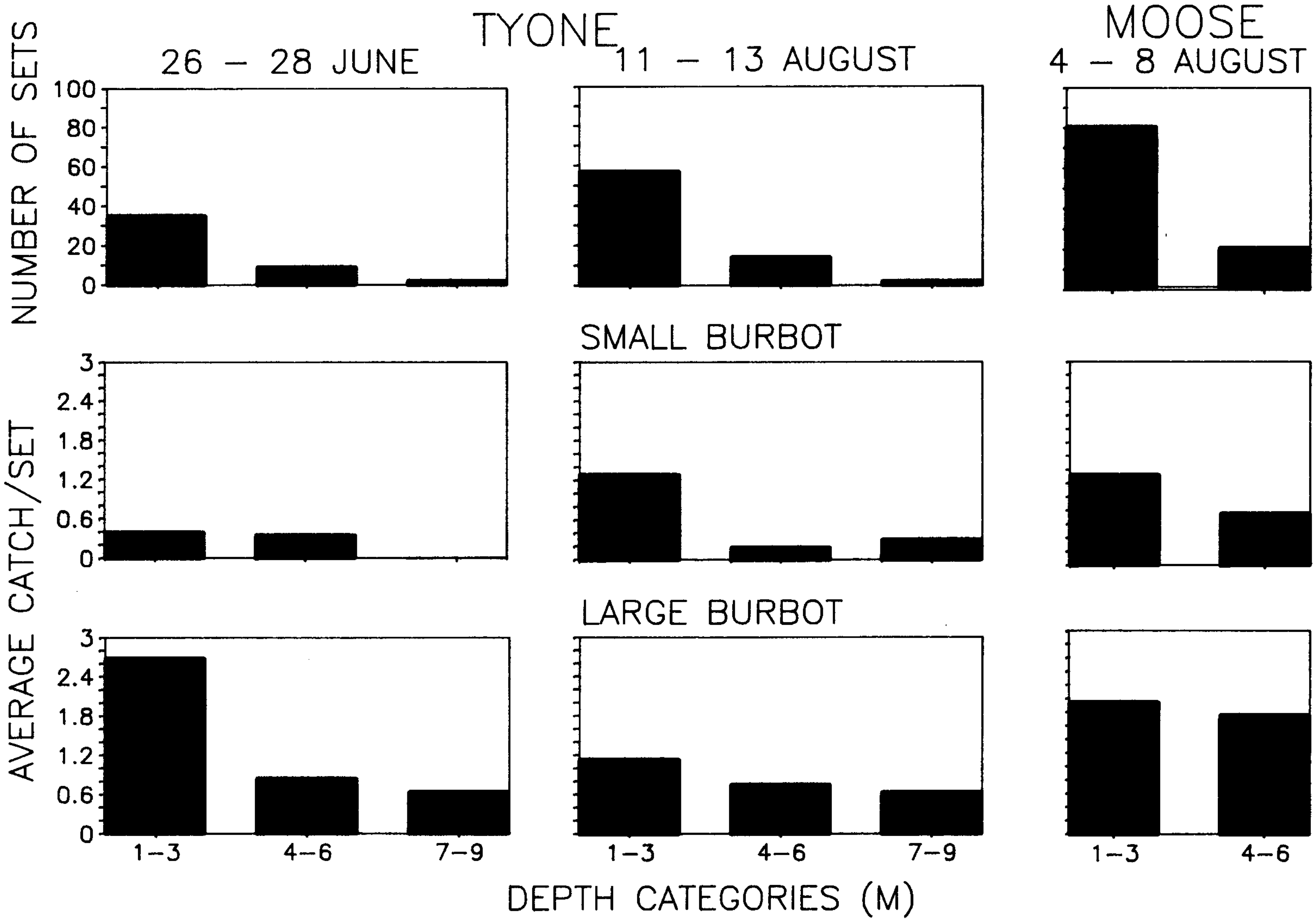
Appendix Figure 5. Frequency of sets by depth and average catch by depth of small (<450 mm TL) and large ($\geq$450 mm TL) burbot for the sampling events in Paxson Lake in 1986.



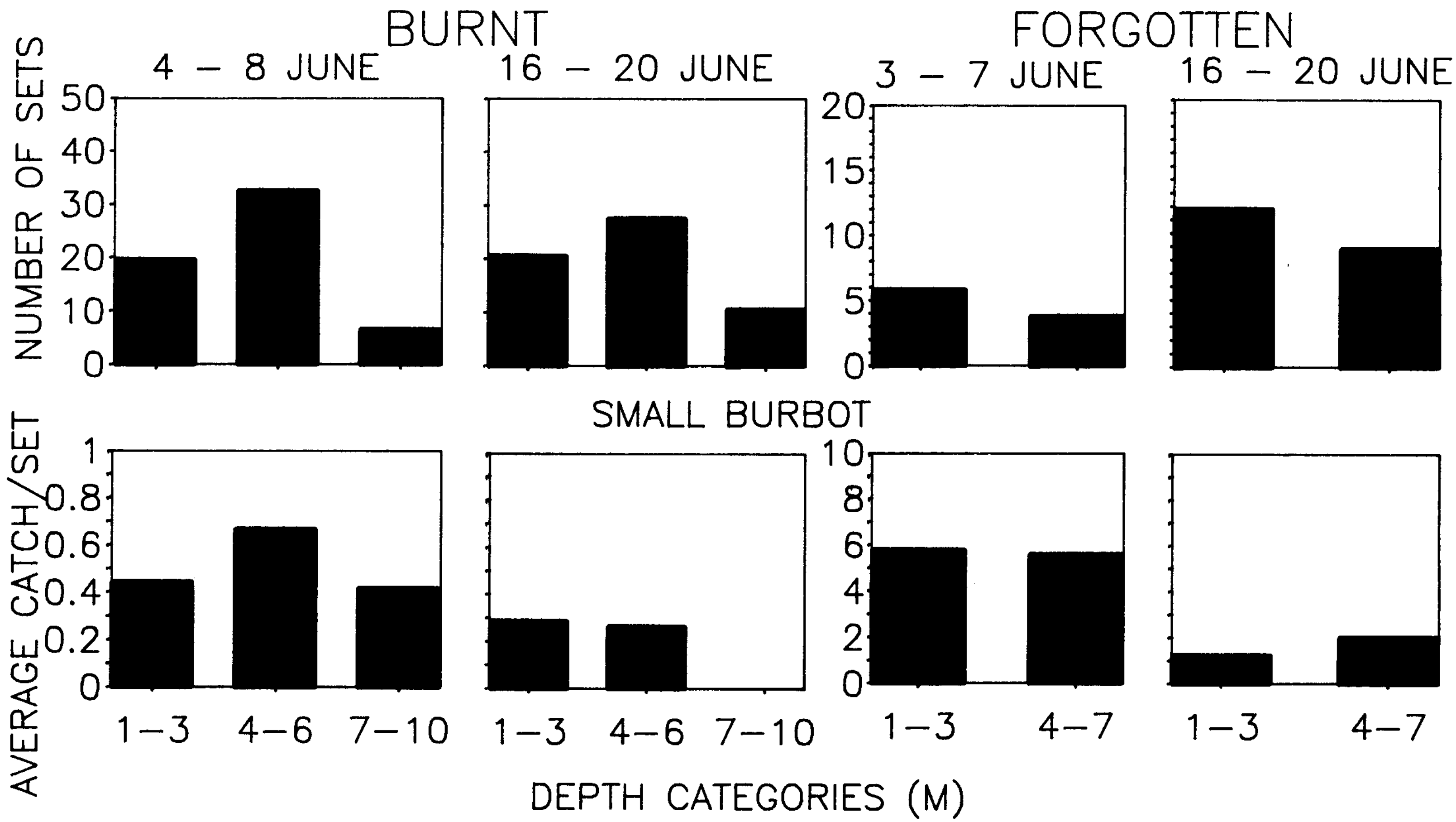
Appendix Figure 6. Frequency of sets by depth and average catch by depth of small (<450 mm TL) and large (≥450 mm TL) burbot for the sampling events in Landlock Tangle, Glacier, and Sevenmile Lakes in 1986.



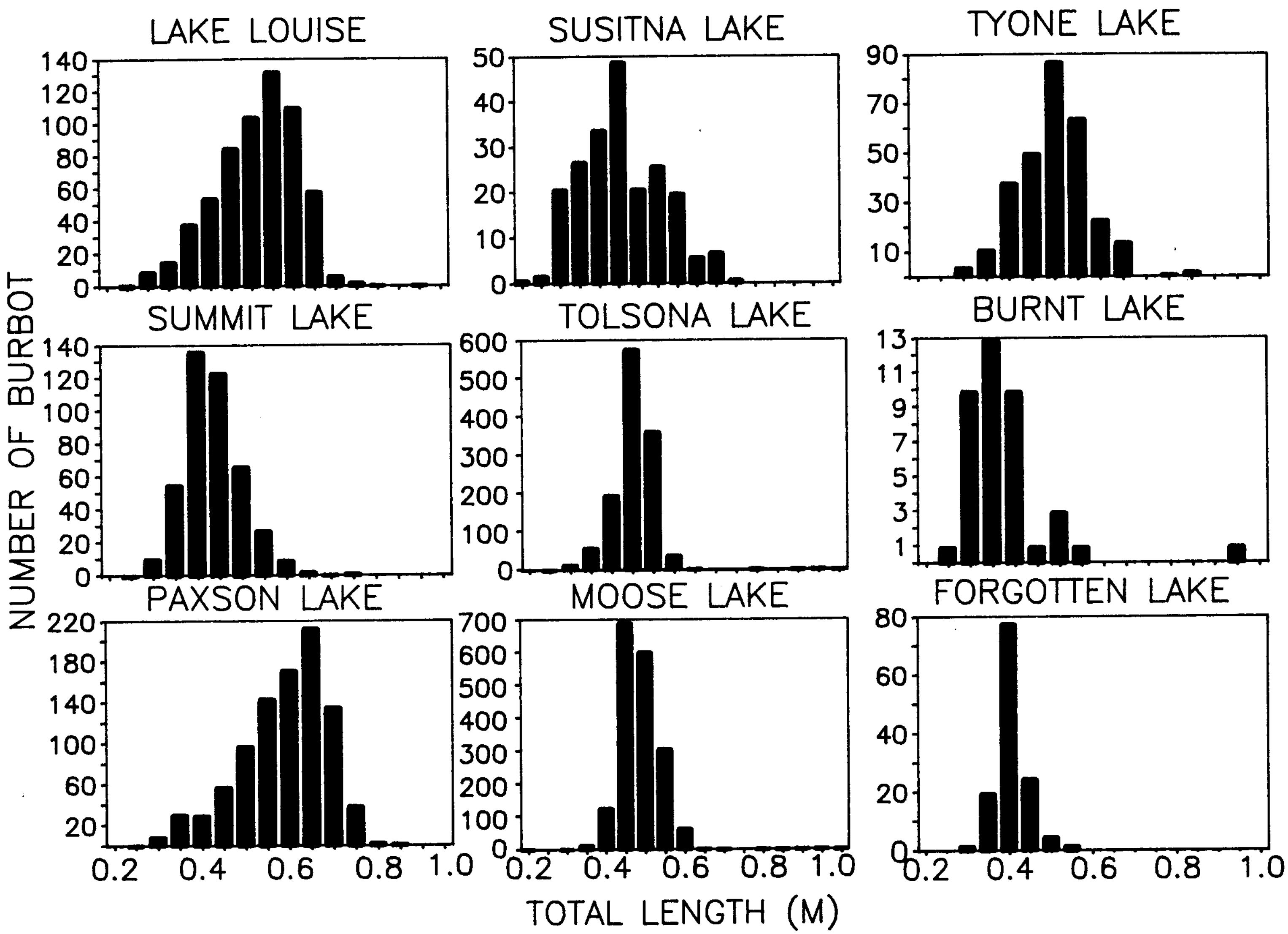
Appendix Figure 7. Frequency of sets by depth and average catch by depth of small (<450 mm TL) and large (≥450 mm TL) burbot for the sampling events in Lake Louise in 1986.



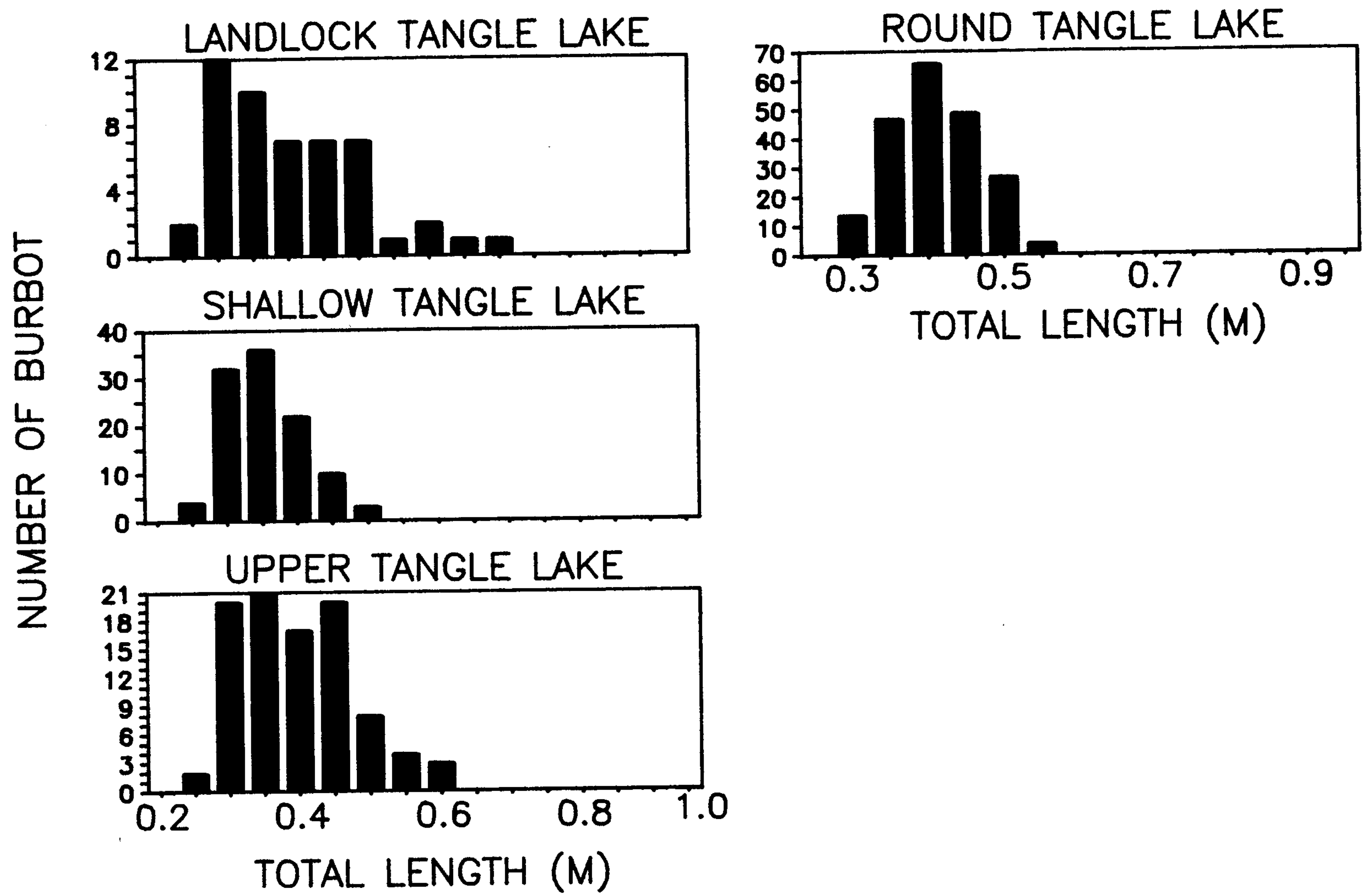
Appendix Figure 8. Frequency of sets by depth and average catch by depth of small (<450 mm TL) and large (≥450 mm TL) burbot for the sampling events in Tyone and Moose Lakes in 1986.



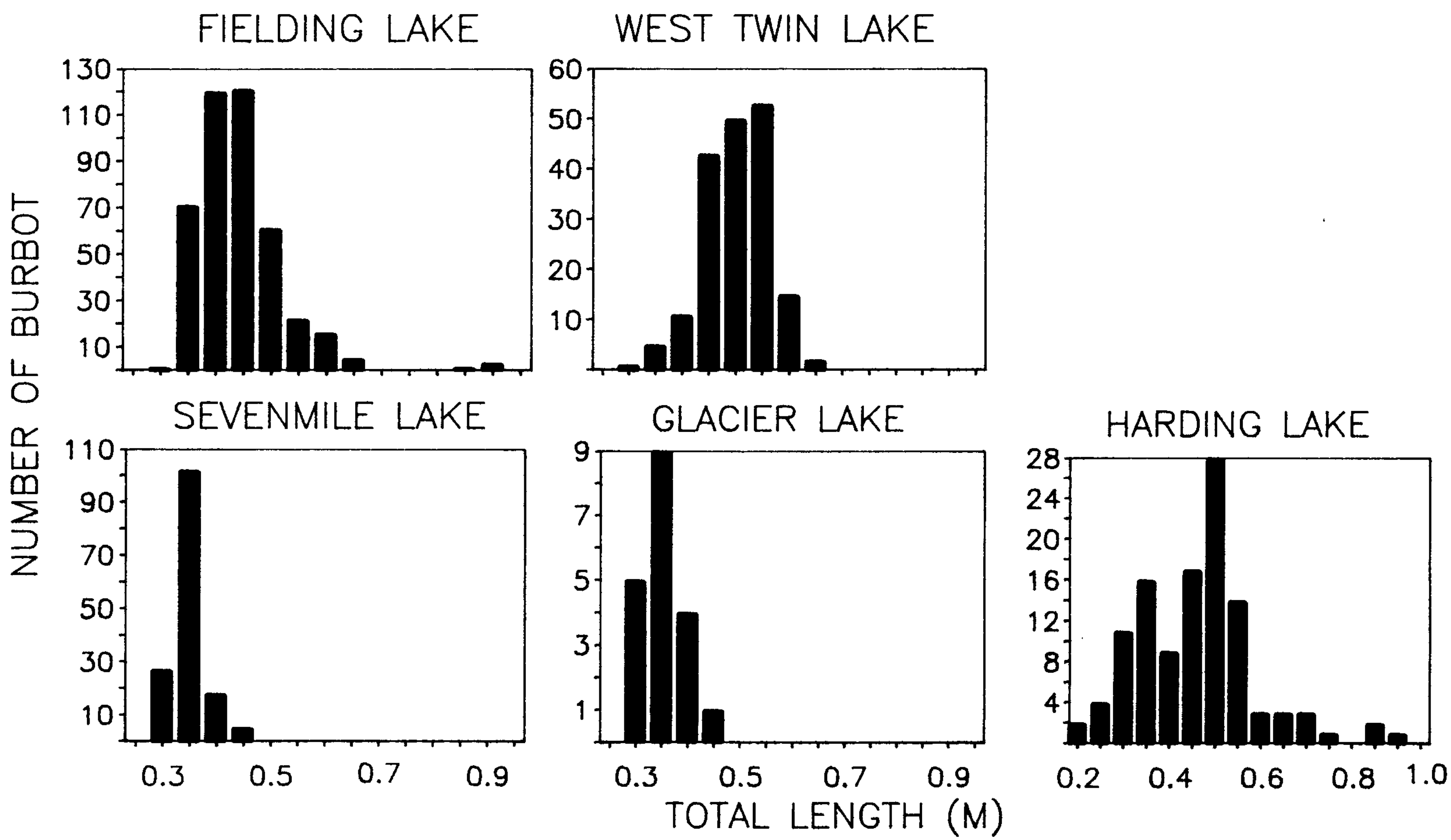
Appendix Figure 9. Frequency of sets by depth and average catch by depth of small (<450 mm TL) burbot for the sampling events in Burnt and Forgotten Lakes in 1986.



Appendix Figure 10. Length-frequency histograms of burbot captured during all sampling events in the Glenallen area of in Interior Alaska in 1986.



Appendix Figure 11. Length-frequency histograms of burbot captured during all sampling events in the Tangle Lakes in the Tanana River drainage of Interior Alaska in 1986.



Appendix Figure 12. Length-frequency histograms of burbot captured during all sampling events in Fielding, Harding, Sevenmile, and West Twin Lakes in the Tanana River drainage of Interior Alaska in 1986.

Appendix Table 2. Standard errors for estimated mean length at age for burbot in Fielding, Harding, Moose, Paxson, Summit, Tolsona, Tyone, and West Twin Lakes and Lake Louise in 1986.

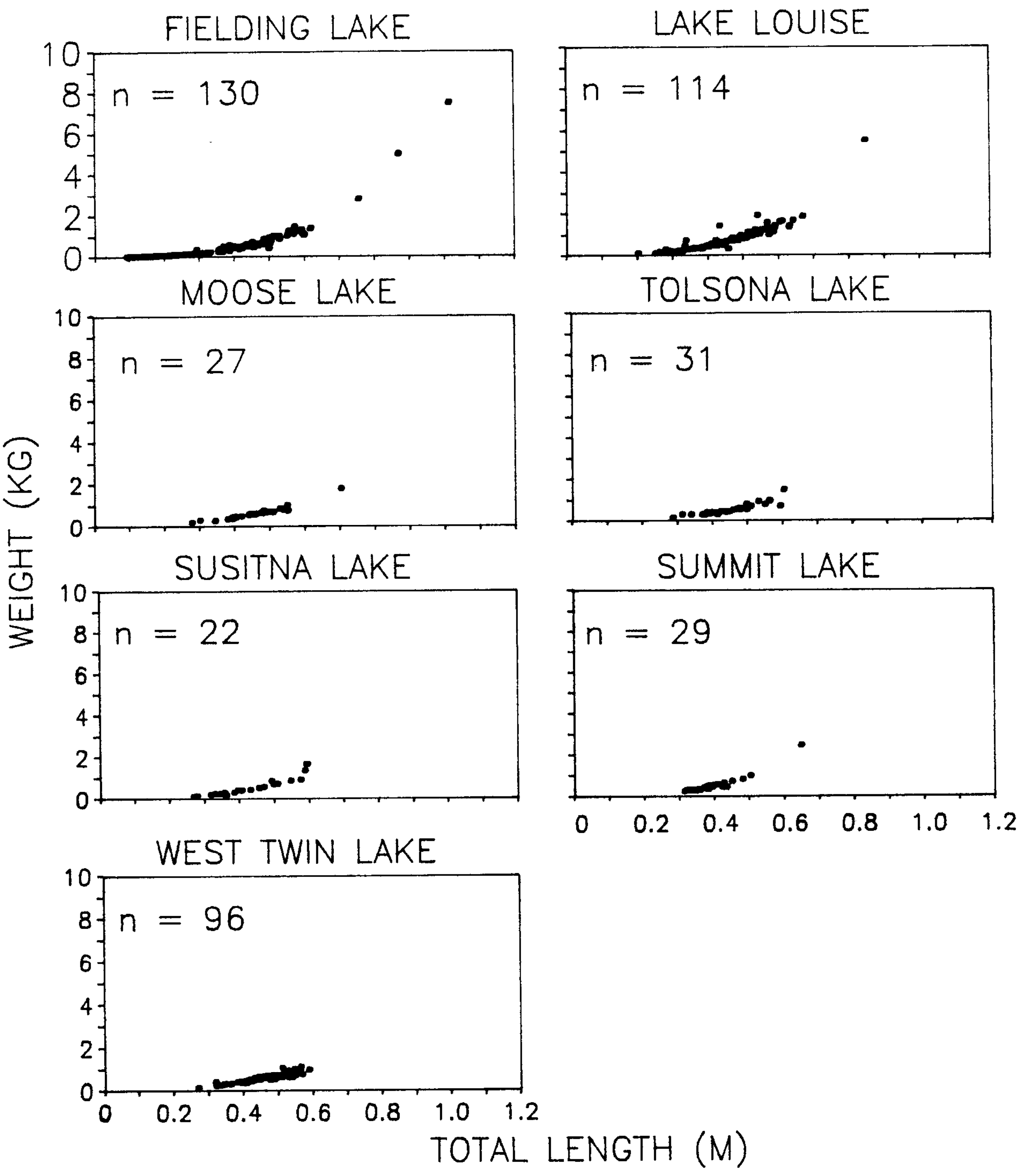
	Fielding				Harding				Louise				Moose			
Age	n[1]	M[2]	F[3]	Both	n	M	F	Both	n	M	F	Both	n	M	F	Both
0	16	3	4	2	0				0				0			
1	20	4	4	4	0				0				0			
2	15	7	9	6	0				4	16	11	9	1			
3	2		7	7	10	42	23	21	8	25	36	21	1			
4	9	14	18	12	9	15		13	11	24	18	15	5		23	23
5	6		9	9	9	33	15	14	23	12	22	12	6		17	17
6	10	24	12	17	7	34	23	21	12	15	20	12	9		12	13
7	20	11	21	12	1				17	11	15	9	4		14	14
8	14	29	22	20	1				13	15	22	17	1			
9	12	18	21	14	1				9	41	10	13	0			
10	1				0				2		38	38	0			
11	2			46	1				1				0			
12	2			93	1				0				0			
13	0				1				1				0			
14	1				0				0				0			
15	0				0				0				0			
16	0				0				0				0			
17	0				0				0				0			
18	0				0				0				0			
All	130	19	21	14	41	26	35	21	101	13	15	10	27		18	17

-Continued-

Appendix Table 2. Standard errors for estimated mean length at age for burbot in Fielding, Harding, Moose, Paxson, Summit, Tolsona, Tyone, and West Twin Lakes and Lake Louise in 1986 (continued).

	Paxson				Summit				Tolsona				Tyone				West Twin			
Age	n	M	F	Both	n	M	F	Both	n	M	F	Both	n	M	F	Both	n	M	F	Both
0	0				0				0				0				0			
1	0				0				0				0				0			
2	0				0				0				0				1			
3	0				0				0				0				2			65
4	7	18	20	13	0				3	6		13	3		25	25	4	44	27	26
5	8	22	10	11	2			5	5	6	10	8	3		14	16	25	13	12	25
6	14	9	11	11	11	21	13	11	2	5		5	1				26	14	11	9
7	15	27	15	14	7	21	29	17	5	21	10	8	2				21	24	14	13
8	20	10	18	11	3	22		28	11	29	8	16	2		32	32	8	12	36	18
9	13	23	19	15	0				0				2		27	27	7	20	34	16
10	9	33	9	14	0				0				5		29	27	0			
11	11	17	17	12	0				0				3		14	14	1			
12	8	1	16	12	0				0				0				0			
13	9	18	53	24	0				0				0				0			
14	1				0				0				0				0			
15	0				0				0				0				0			
16	0				0				0				0				0			
17	0				0				0				0				0			
18	0				0				0				0				0			
All	115	15	13	10	23	13	23	15	26	20	19	14	21		24	23	95	9	9	6

[1] Sample size.
[2] Males.
[3] Females.



Appendix Figure 13. Length and weight data for burbot in Fielding, Moose, Susitna, West Twin, Summit, and Tolsona Lakes, and Lake Louise. Data were collected in 1986 for all populations and in 1982-1985 for the population in Fielding Lake as well.